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**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

APPLICANT: Hideharu Tajima, et al    EXAMINER: Shen, Kezhen

SERIAL NO.: 10/824,926    GROUP: 2627

FILED: April 14, 2004

FOR: OPTICAL DATA RECORDING MEDIUM AND METHOD FOR REPRODUCING RECORDED DATA

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Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

**APPELLANTS' BRIEF ON APPEAL**

In support of Appellants' Notice of Appeal, dated August 28, 2009, from the Examiner's Final Rejection of Claims 1, 3-14, 17 and 18, mailed on May 28, 2009, as maintained in the Notice of Panel Decision from Pre-Appeal Brief for Review dated June 16, 2010, Appellants respectfully submit the following Appellants' Brief on Appeal.

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## BRIEF ON APPEAL FEE

Authorization to charge Deposit Account No. **04-1105** in the amount of $540.00 to cover the cost of this Appeal Brief fee and in the amount of $130.00 to cover the cost of a one-month extension of time to file this Appeal Brief are hereby provided. In addition, if for any reason an additional fee is required to be paid, a fee paid is inadequate or a credit is owed for any excess fee paid, the Commissioner is hereby authorized and requested to charge (or credit) Deposit Account No. **04-1105**.

## BRIEF ON APPEAL CONTENT

This brief contains items under the following headings as required by 37 C.F.R. § 41.37 and M.P.E.P. § 1205.2:

I. Table of Authorities
II. Statement of Real Party In Interest
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# I. TABLE OF AUTHORITIES

## a. Case Law



## b. Manual of Patent Examining Procedure

c. **Statutes and Rules**

## II. STATEMENT OF REAL PARTY IN INTEREST

The real party in interest is Sharp Kabushiki Kaisha, having a principal place of business at 22-22, Nagaike-Cho, Abeno-ku, Osaka-shi, Osaka, JAPAN 545-8522. An assignment of the above-identified application from the inventors Hideharu TAJIMA, Nobuyuki TAKAMORI, Go MORI and Masaki YAMAMOTO to Sharp Kabushiki Kaisha was recorded in the United States Patent and Trademark Office on 14 April 2004 at Reel 015228/ Frame 0640.

## III. STATEMENT OF RELATED CASES

There are no prior or pending appeals, interferences or judicial proceedings known to Appellants, Appellants' representatives, any of the above-identified Assignees (inventors), the above-identified Assignee's (inventors') representatives, or to any inventors, any attorneys or agents who prepared or prosecuted the application on appeal and/or any other person who was substantially involved in the preparation or prosecution of the application on appeal, and that are directly related to, directly affect, or would be directly affected by, or have a bearing on, the Board's decision in this Appeal.

Applicants note for the record, however, that several United States Divisional Patent Applications have been filed since that filing of the present application, each of which claims priority from this application and is currently pending.

## IV. STATUS OF CLAIMS

A. Total Number of Claims in Application

There are 15 claims actively pending in application.

B. Current Status of Claims

Claims canceled, without prejudice: - Claims 2, 15 and 16

Claims withdrawn from consideration but not canceled: - none

Claims pending: - 1, 3-14, 17 and 18

Claims allowed: - none

Claims rejected: - 1, 3-14, 17 and 18

C. Claims On Appeal

The claims on appeal are claims 1, 3-14, 17 and 18

## V. STATUS OF AMENDMENTS

Claims 1, 3-13, 17 and 18 as amended in Appellants' Amendment of 20 February 2009 in the above-identified application are pending on this Appeal. These Claims 1, 3-13, 17 and 18 are the claims finally rejected by the Examiner in the Final Official Action in the above-identified application dated May 28, 2009 and maintained in the Notice of Panel Decision from Pre-Appeal Brief for Review dated June 16, 2010.

There are no unentered Amendments outstanding in the above-identified application.

A clean set of the presently pending claims is reproduced in the attached Appendix Claims Section.

## VI. SUMMARY OF CLAIMED SUBJECT MATTER

### A. OVERVIEW

As will appear more fully below in the recitation of the presently pending claims, including interlineations in italics specifying the support in the present specification for the various limitations thereof, the presently claimed invention generally is an optical data recording medium in which irradiation of a light beam is used for reproducing recorded data and a reproducing method of such an optical data recording medium. More particularly, as is indicated in the present specification *(representatively at Figure 1, Page 7, line 15 to Page 10, last line of the present specification and Page 13, line 8 to Page 14, line 5)*, the recording medium *31* includes a reproduction layer *2* facing a light-incident surface of a substrate *5*, the reproducing layer *2* being for reproducing a signal from a mark having a mark length shorter than a mark length of a resolution limit of an optical system of a reproducing apparatus for reproducing the optical data recording medium. More particularly, the reproducing layer *2* is a layer for the reproduction of a signal from a mark recorded on the medium that has a short mark length smaller than a laser beam spot narrowed by the optical system of the reproducing apparatus. Hence, for example, with an arrangement in which the reproducing layer *2* is made of a material whose transmittance increases upon reception of intensive light or high temperature, only a highly intensive part of the light beam irradiated on the reproducing layer passes through the reproducing layer, thereby giving a smaller beam spot size to the light beam emitted from the reproducing layer. This in turn makes it possible to reproduce a signal from a mark having a shorter mark length than that of the beam spot narrowed by the optical system of the reproducing apparatus.

Furthermore, the reproducing method includes the steps of (i) irradiating the light beam *30* from above the reproducing layer *2*, and (ii) reproducing the mark having a mark length shorter than resolution limit of the optical system of the reproducing apparatus. On the account of foregoing, it becomes possible to reproduce data from an optical data recording medium in which data is recorded in a very high-density.

In a preferred embodiment, the optical data recording medium *31* includes a reflective layer *4*, a light-absorption layer *3* and a reproducing layer *2* layered in that order on a substrate *5*. A laser beam *30* is irradiated from above the reproducing layer *2*, through the light-absorption layer *3* and thence to the reflection layer *4* that conforms to a plurality of pits and grooves (areas of rise and/or recess) on the light incident surface of the substrate *5*. *(see Pages 12-13).* The reflective layer *4* reflects the laser beam *30* that has passed through the reproducing layer *2* and the light-absorption layer *3* in the form of reproducing signals in accordance with the quantity of that incident light beam *30* (which varies in accordance with the rise and/or recessed nature of the underlying pitted surface of the substrate). The light absorption layer *3* is adapted to convert the light passing through it to heat in accordance with the intensity of that light and to transfer that heat so produced to the reproducing layer *2* contiguous thereto. The reproducing layer *2*, on the other hand, has a variable transmittance that changes reversibly with changes in its temperature. Hence, the transmittance of the reproducing layer *2* is selected such that it increases only in a temperature rising part of the reproduction laser beam *30* (which is a small spot near the center of the laser beam spot *30*). In this way, the diameter of the laser beam spot of the laser beam *30* that passes through the reproducing layer *2* is smaller than that of the incident laser beam *30* whereby the reproduction of shorter mark lengths than the optical resolution capability of the reproduction system is achieved.

The novelty and nonobviousness of the claims of this application will be discussed in detail below. Suffice it to note at this stage that with respect to the claims that are currently the subject of this Appeal, Appellants respectfully submit that specific support for the various limitations thereof appears in the present specification at least as follows:

**B. CLAIMS**

1. (Rejected) An optical data recording medium *(31, see Fig. 1, Page 12, lines 8-20)*, in which irradiation of a light beam *(30, see Fig. 1, paragraph bridging pages 12 and 13)* is used for reproducing recorded data, comprising:

a substrate *(5, see Fig. 1)* having pits *(see, Fig. 1 and Page 13, lines 6-21)* disposed on a light incident surface thereof *(i.e., " that surface of the substrate 5 from above which the laser light beam 30 is irradiated (from the optical system); that is that surface of the substrate 5 above which the reproducing layer 2 is provided" see Page 13, lines 8-11 and Fig. 1)*, corresponding to the recorded data, which are shorter than a resolution limit of an optical system of a reproducing apparatus which reproduces that optical data recording medium *( see page 39, last paragraph to Page 40, paragraph 3)*; and

a reproducing layer *(2, see Fig. 1)* for improving the resolution of optical signals from said pits *( see Page 17, line 7 to Page 21, line 1, particularly paragraph bridging pages 20 and 21)* and passing said improved resolution optical signals from said pits to said optical system of said reproducing apparatus in a form reproducible by said reproducing apparatus, the reproducing layer *(2)* being provided so as to face said light-incident surface of said substrate *(5)*.

2. (Canceled, without prejudice)

3. (Rejected) The optical data recording medium *(31)* as set forth in Claim 1, wherein:

the reproducing layer *(2)* is made of a material whose transmittance changes in accordance with temperature. *(see Page 17, line 8 to Page 18, line 24)*

4. (Rejected) The optical data recording medium *(31)* as set forth in Claim 1 wherein:

at least a part of a light-incident surface of the reproducing layer *(2)* is exposed to air. *("In the optical data recording media 31, the cover layer 1 does not completely adhere to the reproducing layer 2, and a layer of air is formed between the cover layer 1 and the reproducing layer 2. A laser beam 30 is irradiated, from above the cover layer 1, to the optical recording medium 31. The laser beam passes through the cover layer 1 and the layer of air, and reaches the reproducing layer 2." see Page 12, lines 16 – 24)*

5. (Rejected) The optical data recording medium *(31)* as set forth in Claim 1 further comprising:

a light absorption layer *(3, see Fig. 1)* for converting an incident light beam *(30)* directed toward said light incident surface of said substrate *(5)* to heat, the light absorption layer *(3)* being contiguous to the reproducing layer *(2)*. *(see Page 15, lines 12 – 19 regarding heat generation; see also Page 16, lines 12-19 regarding contiguous disposition of layers; and further Page 12, lines 13-15, "The reflective layer 4, the light absorption layer 3, reproducing layer 2 are layered on substrata 5* ***in this order"***. Emphasis added*)*

6. (Rejected) The optical data recording medium *(31)* as set forth in Claim 1 further comprising:

a reflective layer *(4, see Fig. 1)* for reflecting an incident light beam directed toward said light incident side *(as described previously above)* of said substrate *(5)*, the reflective layer *(4)* being provided between said light incident side of said substrate *(5)* and said reproducing layer *(2)*. *(see Page 12, lines 13-15, "The reflective layer 4, the light absorption layer 3, reproducing layer 2 are layered on substrata 5* ***in this order"***. Emphasis added*)*

7. (Rejected) The optical data recording medium *(31)* as set forth in Claim 1 wherein:

the reproducing layer *(2, see Fig. 1)* is made of a metal oxide. *(see Page 18, lines 8 – 24)*

8. (Rejected) The optical data recording medium *(31)* as set forth in Claim 7, wherein:

the reproducing layer *(2, See Fig. 1)* is made of a zinc oxide. *(see Page 18, last line to Page 19, line 21)*

9. (Rejected) The optical data recording medium *(31, see Fig. 1)*as set forth in Claim 5, wherein:

the light absorption layer *(3, see Fig. 1)* is made of one of silicon, germanium and an alloy of silicon and germanium. *(see Page 15, line 20 to Page 16, line 3)*

10. (Rejected) An optical data recording medium *(31, see Fig. 1)*, in which irradiation of a light beam (30) is used for reproducing recorded data, comprising:

a substrate *(5, see Fig. 1)* having a light incident surface containing pits, corresponding to the recorded data, which are shorter than a resolution limit of an optical system which reproduces the optical data recording medium *(see Page 13, lines 6 to 21)*;

a reproducing layer *(2, see Fig. 1)*, stacked on the light incident surface of the substrate *(5)* in which the pits are provided, the reproducing layer *(2, see Fig. 1)* having a changeable transmittance with respect to an irradiated light beam *(30)* irradiated on the reproducing layer *(2)* and directed toward said light incident surface of said substrate *(5)*, the changeable transmittance being changeable in accordance with an intensity distribution of the light beam irradiated on the reproducing layer *(2) (see also Page 17, lines 7 to 21)*; and

a reflective surface *(4, see Fig. 1)*, provided between the substrate *(5)* and the reproducing layer *(2)*, for reflecting a light beam that has passed through the reproducing layer *(2)*.

11. (Rejected) The optical data recording medium *(31, see Fig. 1)* as set forth in Claim 10, further comprising:

a reflective layer *(4, see Fig. 1)* provided between the substrate *(5, see Fig. 1)* and the reproducing layer *(2, see Fig. 1)*, and including the reflective surface *(see paragraph bridging Pages 14 and 15)*.

12. (Rejected) The optical data recording medium *(31, see Fig. 1)* as set forth in Claim 10, further comprising:

    a light absorption layer (3, see Fig. 1), provided between the substrate *(5)* and the reproducing layer *(2)*, for converting, to heat, the light beam irradiated thereon *(see Page 15, lines 12 to 19)*.

13. (Rejected) The optical data recording medium *(31, see Fig. 1)* as set forth in Claim 10, wherein:

    at least a part of that surface of the reproducing layer *(2)* which is a reverse surface to the surface facing the substrate *(5)* is exposed to air. *("In the optical data recording media 31, the cover layer 1 does not completely adhere to the reproducing layer 2, and a layer of air is formed between the cover layer 1 and the reproducing layer 2. A laser beam 30 is irradiated, from above the cover layer 1, to the optical recording medium 31. The laser beam passes through the cover layer 1 and the layer of air, and reaches the reproducing layer 2." see Page 12, lines 16 – 24)*

14. (Canceled, without prejudice)

15. (Canceled, without prejudice)

16. (Canceled, without prejudice)

17 (Rejected) A reproducing method of an optical data recording medium *(31, see Fig. 1)* in which irradiation of a light beam *(30)* is used for reproducing data recorded in the optical data recording medium,

said optical data recording medium *(31)* including:

a substrate *(5)* having a light incident surface containing pits, corresponding to recorded data, which are shorter than a resolution limit of an optical system of a reproducing apparatus which reproduces the optical data recording medium; and

a reproducing layer *(2)* for improving the optical resolution of optical signals from said pits and passing said improved resolution optical signals to said optical system of said reproducing apparatus in a form reproducible by said reproducing apparatus,

the reproducing layer *(2)* being provided so as to face said light-incident surface of the substrate *(5)*,

said reproducing method comprising the step of:

irradiating the light beam *(30)* from above the reproducing layer *(2)* to the light incident surface side of said substrate *(5)* so as to reproduce the pits. *(see comments regarding Claim 1 above as well as Page 21, line 22 to Page 24, last line –particularly, paragraph bridging pages 22 and 23)*

18. (Rejected) A reproducing method of an optical data recording medium *(31, see Fig. 1)* in which irradiation of a light beam is used for reproducing data recorded in the optical data recording medium,

said optical data recording medium *(31)* including:

a substrate *(5)* containing pits in a light incident side thereof, corresponding to the recorded data, which are shorter than a resolution limit of an optical system of a reproducing apparatus which reproduces the optical data recording medium;

a reproducing layer *(2)* stacked on the light incident surface of the substrate *(5)* in which the pits are provided, the reproducing layer *(2)* having a changeable transmittance with respect to an irradiated light beam irradiated on the reproducing layer and directed toward said light incident side of said substrate *(5)*, the changeable transmittance being changeable in accordance with an intensity distribution of the light beam irradiated on the reproducing layer *(2)*; and

a reflective surface, provided between the substrate *(5)* and the reproducing layer *(2)* for reflecting a light beam that has passed through the reproducing layer *(2)*,

said reproducing method comprising the step of:

reproducing said recorded data by irradiating a light beam (30) onto said optical data recording medium *(31)* from above the reproducing layer *(2)*. *(see comments regarding Claim 1 above as well as Page 21, line 22 to Page 24, last line –particularly, paragraph bridging pages 22 and 23)*

## VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

**A.** The grounds of rejection to be reviewed on this Appeal, are:

1. Whether claims 1, 3-13, and 17-18 would have been obvious to a person of ordinary skill in the art at the time that the invention of the above-identified application was made within the meaning of 35 U.S.C. §103(a) over Tominaga et al (US Patent No. 5,569,517 – Evidence Appendix Exhibit I) in view of Jung (US Patent No. 5,516,568 – Evidence Appendix Exhibit II); and

**B.** All of the finally rejected dependent claims of this application stand or fall with their respective associated base independent claim.

## VII. ARGUMENT

### A. STANDARDS OF OBVIOUSNESS UNDER 35 USC 103(a)

The standards required to be satisfied in order to support a holding of "obviousness" under 35 USC 103(a) are well defined as follows:

> "To establish a *prima facie* case of obviousness under Section 103, Title 35 United States Code (35 USC §103), three basic criteria must be met. First, ***there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings***. Second, there must be a reasonable expectation of success. Finally, ***the prior art reference (or references when combined) must teach or suggest all of the claim limitations. The teaching or suggestion to make the claimed combination and the reasonable expectation of success must both be found in the prior art, and not based on Applicants' disclosure***." *In re Vaeck*, 947 F.2d 488, 20 USPQ2d 1438 (Fed. Cir. 1991). (See, Manual of Patent Examining Procedure §2142 (8th Edition), at page 2100-2121, *et seq.*) *Emphasis added*

Accordingly, unless the Examiner establishes a satisfactory ***prima facie*** case in support of his rejections under 35 USC 103(a), his rejections should be vacated on this Appeal.

Furthermore, according to Section 2143.01 (III) of the Manual of Patent Examining procedure (MPEP), it is settled law that "[t]he mere fact that a reference ***can*** be combined or modified does not render the resultant combination obvious unless the prior art suggests the desirability of the combination". *In re Mills*, 916 F.2d 680, 16 USPQ2d 1430 (Fed. Cir. 1990) Also, it is impermissible simply to engage in hindsight reconstruction of the claimed invention, using applicant's structure as a template and selected elements from the references to fill the gaps. *In re Gorman*, 18 USPQ2d 1885 (Fed. Cir. 1991) Further still, Section 2143.01(VI) of the Manual of Patent Examining Procedure makes it abundantly clear that in order for a disclosure of a reference to conform with the standards for the establishment of a *prima facie* case supporting a rejection under 35 USC 103, the proposed modification of the prior art embodied in a claim of an application cannot change the principal of operation of the prior art reference being applied. In other words, if the proposed modification or combination of the prior art relied upon by the Examiner would change the principal of operation of the prior art invention being modified in an attempt to reach the present invention, then the teachings of the combined references ***are not*** sufficient to establish a *prima facie* case of obviousness under the appropriate standards for the same. *In re Ratti*, 280 F.2d 810, 123 USPQ 349 (CCPA, 1959)

Applicants respectfully submit that all of the foregoing criteria are relevant to the ultimate determination of this Appeal.

## B. DISCUSSION

### 1. Whether claims 1, 3-13 and 17-18 would have been obvious to a person of ordinary skill in the art at the time that the invention of the above-identified application was made within the meaning of 35 U.S.C. §103(a) over Tominaga et al (US Patent No. 5,569,517) in view of Jung (US Patent No. 5,516,568).

#### a. The Outstanding Final Rejection

In the currently outstanding Final Official Action in the above-identified application, the Examiner has alleged that Tominage et al. (US Patent No. 5,569,517) teaches an optical data recording medium, in which irradiation of a light beam is used for reproducing recorded data (reading light of Figs. 1 and 2). In this regard, the Tominaga et al structure is alleged to include a substrate having pits (10 and 21 of Fig. 2, Col. 4, lines 15-28) corresponding to the recorded data. *Appellants do not agree that the reference numeral 10 refers to pits. It is respectfully submitted that the Tominaga reference numeral 10 refers to the protective layer.* Furthermore, the Examiner alleges that the pits disclosed by the Tominaga et al reference are shorter than a resolution limit of an optical system of a reproducing apparatus which reproduces the optical data recording medium (Col 2, lines 24-35 and Column 10, lines 7-20) and suggests that super resolution is the ability to read an image beyond the diffraction limit resolution. *As will appear more fully below, Appellants do not agree that the Tominaga et al reference discloses pits that are shorter than the optical resolution limit of the associated optical system.* Further, the Examiner alleges that Tominaga et al includes a reproducing layer for improving the resolution of optical signals from said pits and passing said improved resolution optical signals from said pits to said optical system and said reproducing apparatus in a form reproducible by said reproducing apparatus (3 of Fig. 2, Column 3, lines 38 - 55, Column 4, lines 20-28 the mask layer of the transmittance control layer increases the resolution of the read out).

The Examiner admits, however, that the Tominaga et al reference fails to teach the pits are disposed on a light-incident surface of the substrate and the reproducing layer is provided so as to face the light incident surface of said substrate. However, the Examiner alleges that the Jung (US Patent No. 5,516,568) reference teaches an optical data recording medium wherein the recording layer is the light-incident surface and the reproducing layer is provided to face said light-incident surface(Jung 5 of Fig. 1, Column 4 lines 38-51) From this, the Examiner alleges that one of ordinary skill in the art would have recognized the ability to replace the change transferring (charge-transferring??) material of the Jung reference to lands and pits as in the present invention).

*Appellants do not agree with the Examiner's conclusion concerning the obviousness of replacing the change transferring (meaning "charge-transferring"?) material of Jung with lands and pits as in the present invention. Appellants note in this regard that in the Jung reference, the information is stored on the outer surface of the outer recording layer 5, not the surface of the substrate or any of the layers between the outer layer 5 and the substrate. Furthermore, during information reproduction a laser beam of lesser intensity than that of the laser beam intensity used in recording (i.e., incapable of generating a charge) is scanned across the outer surface of the recorded medium 5, with a technique being employed to reproduce information relying upon the difference of the light transmitted through or reflected from the optical recording medium 5 (see Jung, Column 5, lines 1-7). In other words, in Jung information is recorded by charges generated in the charge generating layer 3 in response to an incident laser beam of a predetermined wavelength that is absorbed by the charge generating layer 3 which charges are transferred to the outer surface of the recording layer 5, not to a light-incident surface of the substrate 1, and thereafter read by differences in the transmittance of the recording layer 5 caused thereby. Such is respectfully submitted to be totally different in concept and means from thermally (or light intensity) controlling a mask layer so as to adjust the resolution of a laser beam incident thereon as in the present invention on its way toward a pitted information containing surface of a substrate.*

Then, by taking the alleged teachings of Tominaga et al and Jung "as a whole", the Examiner asserts *(erroneously in Appellants' estimation)* that one of ordinary skill in the art would be motivated to combine the teachings of an optical data recording medium with the teachings of a recording and reproducing layer on the surface of the light-incident surface for the benefit of an increase in the data density of the optical disc and long archival capability (citing Jung Column 3, lines 55-61)

**b. Pits Shorter Than The Resolution Limit Of An Optical System In The Reproducing Apparatus**

During the course of the present prosecution, Appellants have agreed that Tominaga et al., in Figures 1 and 2, depicts pits 21 that are ***shorter than the diameter $\varphi_0$ of a reading light beam***. Nevertheless, Appellants respectfully submit that ***this is insufficient to anticipate or render obvious the feature of the present claims that specifies "pits disposed on a light incident surface thereof, corresponding to the recorded data, which are shorter than a resolution limit of an optical system of a reproducing apparatus which reproduces the optical data recording medium***".

In support of the foregoing assertion, Appellants respectfully note that the beam spot diameter in devices of the type herein claimed is generally and conventionally denoted by those skilled in the art as $\lambda$/NA ($\lambda$: being the wavelength of read light beam, and NA being the numerical aperture). In contrast to this, ***the typical optical resolution limit of such an optical system is generally denoted by $\lambda$/(4NA)***, that is as being equal to one quarter (1/4) of the beam spot diameter.

Accordingly, Appellants respectfully submit that when one skilled in the art views the pits shown in Figures 1 and 2 of Tominaga et al. bearing the latter facts in mind, it clearly appears that the pits depicted by Tominaga et al are ***longer than the optical resolution limit referred to in the claims*** of the present application. Furthermore, Appellants respectfully submit that it should be recognized that the Tominaga et al. reference ***does not anywhere explicitly teach*** pits shorter than the resolution limit of an optical system of an associated reproducing apparatus.

The present specification at page 39, last paragraph to Page 40, paragraph 3, on the other hand, clearly and distinctly describes the use of pits less than 0.14 µm, that is shorter than the optical resolution limit, in securing sufficient signal quality (i.e., optical resolution limit: 0.16µm = 408 nm/ (4 x 0.65) – see specification at page 39, paragraph 2).

Indeed, in this regard, the Examiner previously in this prosecution has admitted that the Tominaga reference ***does not teach that the pits are less than the optical resolution limit as calculated by λ/(4NA). Nevertheless, however, the Examiner has maintained that one of ordinary skill in the art would understand that Tominaga is teaching pits shorter than the normal optical resolution limit by inference from the sections at Column 2, lines 24-35 and Column 10, lines 7-20 of the Tominaga et al specification***. Appellants respectfully submit in this regard that the Examiner has based the foregoing position upon a totally unsupported belief that the only variable that accounts for the changes in super resolution discussed by the Tominaga et al reference is changes in pit length thereby making the presently claimed pit lengths inherent in the Tominaga et al disclosure.

Appellants do not agree.

In support of this position, Appellants respectfully note that the Tominaga et al reference does not characterize the prior art referred to in the Background section of its specification at Column 2, lines 24-35 in the manner referred to above, i.e., as shorter than the normal optical resolution limit of the reproducing optical system. Appellants believe that this is because the art described in the Background section of the Tominaga et al reference is different from and not specifically relevant to the Tominaga Fig. 2 invention.

Thus, it will be recognized that while the materials referred to by Tominaga at Col. 2, lines 24-35 are very generally suggested therein to achieve higher resolutions than the incident light beams ("This material layer is provided for achieving higher resolution beyond the limit determined by the reading light wavelength l and the objective lens numerical aperture NA…"), those materials are different from the materials that Tominaga et al discusses with respect to his Fig. 2. Also, Tominaga et al never quantifies the length of the phase pits referred to as being optically read in the Background portion of their specification. Furthermore, in this regard, and significantly, in the currently outstanding Final Official Action at Page 2 the last sentence of the second full paragraph, the Examiner indicates that the background section of the Tominaga et al reference to which he has repeatedly referred as disclosing the presently claimed pit lengths is now relied upon "merely to clarify what is referred to at Column 10, lines 7-20 thereof" that he is using as an inferential teaching of the present invention.

Consequently, Appellants respectfully submit that while Tominaga may indicate generally that reproducing layers are present in the art that can improve the resolution of information derived from pits in a substrate surface, nothing in Column 2, lines 24-35 of Tominaga et al (or any other location in the art currently of record in this proceeding) is sufficient to anticipate (or render obvious) the present invention as presently claimed. This is because there is simply no disclosure, teaching or suggestion regarding the length of the so-called "phase pits" relative to the optical resolution limit of the optical system provided by the Tominaga et al reference in this (or indeed any) regard.

Appellants also respectfully submit that the same is true with respect to the Examiner's comment that "super resolution is the ability to read an image beyond the diffraction limit resolution". More particularly, it is Appellants' position that without any specification teaching, disclosing or suggesting the specific quantitative relationship between the optical system resolution and the length of the pits, it is simply not possible to justify a position that the Tominaga et al reference somehow ***anticipates or otherwise renders unpatentable the present claims that do specify the quantitative relationship in question by the resort to some sort of undefined inference supposedly apparent to one of ordinary skill in the art at the time that the present invention was made.***

Appellants, therefore, respectfully emphasize that the Tominaga et al reference specifically refers only to a ***suggestion (i.e., an inference, to use the Examiner's phraseology)*** that the results of at least one of the experiments described in their specification is that a higher resolution is achievable with a material that changes its reflectance with temperature. Specifically, Tominaga et al at Column 10, lines 7-20, mention a "super-resolution read out" (Col. 10, lines 19-20). However, the term "super resolution" appears in a sentence beginning with "This suggested that ...". Appellants respectfully submit therefore that he entire sentence in question gives rise only to a ***mere possibility*** of a "super-resolution read-out", not solid evidence disclosing or otherwise evidencing the technique suggested (inferred) by the Examiner. Thus, Appellants respectfully submit that the just-referred-to statement in the Tominaga et al reference, like the related statement from the Background section of the Tominaga et al reference alluded to above, even if true, is not sufficient to justify the expansive conclusions concerning the relationships between pit length and optical system resolution that the Examiner has chosen to draw from it.

Hence, it is Appellants' belief that neither of the portions of the Tominaga et al reference referred to by the Examiner (and noted above) is sufficient to constitute a reduction to practice by Tominaga, et al of the super resolution disclosed and claimed in the present application. Accordingly, Appellants respectfully submit that the Examiner has not justified his conclusion determining the unpatentability of the present application based thereon (i.e., the Examiner has not established the required ***prima facie case in support of his rejection***).

Consequently, Appellants respectfully submit that Tominaga et al does not inherently teach, disclose or suggest to one skilled in the art as of the time that the present invention was made that so-called "super resolution" technology delivers a desired performance when the length of the pits that are the signal source are at or below the optical resolution limit of the associated optical system. The Tominaga et al reference's broad and generalized suggestion (inference) that it achieves a higher resolution limit than the optical resolution of the input light beam from the associated optical system simply ***does not*** constitute a teaching, disclosure or suggestion that that higher resolution limit originates ***only and/or necessarily*** with signals reproduced from pits shorter than the resolution limit of the optical system.

Stated slightly differently, even if the Tominaga et al reference arguably might be said to infer that it obtains a higher resolution than the optical resolution limit of its associated optical system, that inference alone and taken only in and of itself in Appellants' estimation ***cannot*** be taken as a disclosure to one of ordinary skill in the art at the time that the present invention was made that the Tominaga results are achieved with pit lengths shorter (or for that matter longer) than the optical resolution of the associated optical system.

The broad and general overall concept of super resolution may be present to some limited extent in Tominaga et al disclosure, but as far as Appellants can see the Tominaga et al disclosure nevertheless is clearly and totally insufficient to teach, disclose or suggest whether its results are achievable with pits that are shorter and/or longer than the optical resolution of the associated optical system. This is particularly because none of those quantitative measurements is contained anywhere in the Tominaga et al disclosure or anywhere else in the art relied upon by the Examiner in this application.

Hence, Appellants believe that the Tominaga et al disclosure is insufficient to teach or disclose or suggest to one of ordinary skill in the art at the time that the present invention was made what the lengths of the pits should be in order to achieve "super resolution". Appellants also believe that the foregoing should again be contrasted with the fact that the present invention teaches unequivocally and specifically that the pit length should be shorter than the optical resolution of the associated optical system when "super resolution" is achieved.

In addition, the crystal-to-liquid or amorphous-to-liquid materials mentioned by Tominaga at Col. 2, lines 24-35 are suggested to achieve higher resolutions than the resolution limit of the associated optical system (i.e., at least greater than the resolution achievable with the input reading light beam). Those materials are admitted by the Examiner to be different from, ***and to function differently from***, the materials that Tominaga et al discusses with respect to his Fig. 2 that utilize a crystal-to-crystal transition to effect a super resolution capability that may increase or decrease reading light reflectivity and hence resolution. (see Tominaga at Col. 4, ln 65 to Col. 5, ln 54).

Accordingly, since the discussion at Col. 10, lns 7-20, of Tominaga only ***suggests (infers)*** that a crystal-to-crystal type of super resolution read out was obtained in one example, and did so without specifying the size of the pits involved in storing information, Applicants respectfully again submit that the actual disclosure of the Tominaga reference relied upon by the Examiner does not specifically support the inferences that the Examiner chooses to draw from it, i.e., so-called "super resolution" technology delivers a desired performance when the length of the pits are at or below the optical resolution limit of the associated optical system. Indeed, so-called "super resolution technology" does not always deliver desired performance from pits having lengths at or below the optical resolution limit. In particular, as the following analysis shows, the pit length in some super resolution technologies can be longer than the optical resolution when "super resolution" is achieved thereby rendering the Examiner's "inherent teaching" basis for the currently outstanding rejections in the currently outstanding rejections untenable.

Accordingly, Appellants respectfully submit that it should be recognized that in actuality, as the mark (i.e., pit) length approaches the optical resolution limit of the associated optical reproduction system in an ordinary optical information storage medium one cannot obtain the requisite strength (ex. C/N) of signals reproduced from marks longer than the optical resolution limit. The technology that improves the signal strength from such marks, even if the marks are longer than the resolution limit, is sometimes described as "super resolution. See, for example, *Exhibit III in the Evidence Appendix* hereto dealing with magnetically induced super resolution and the following analysis that shows that the mark (i.e., pit) lengths in the disclosed magnetically induced super resolution context are ***longer than the optical resolution limit.***

Consequently, Applicants respectfully submit that the Tominaga et al reference is insufficient to teach, disclose or suggest what the length of the pits should be in a system that achieves "super resolution" despite the Examiner's attempt to impute some sort of inherent disclosure to the Tominaga et al reference that is respectfully submitted to not really be there.

**Analysis of Exhibit I in Evidence Appendix (magnetic super resolution) in comparison to Blu-Ray Disc of Exhibit II in Evidence Appendix**

In support of Appellants' assertion that the pit length can be ***longer than the optical resolution of the optical system*** in some cases wherein so-called super resolution is achieved, Appellants respectfully direct attention to Exhibits III and IV of the Evidence Appendix which may be identified as follows:

1. Proc. SPIE 4342,252 (2002) 50-mm CAD-MSR Disk System with Blue Laser, Y, Murakami, et al – See Exhibit III of Evidence Appendix

2. "New Anatomy of Next –generation Optical Discs: In-depth Analysis (with partial English language translation of relevant sections) – See Exhibit IV of Evidence Appendix

The minimum mark length described in Exhibit III (that describes magnetically induced super resolution) above can be calculated through a comparison with Exhibit IV above as follows:

The Abstract of Exhibit III specifically indicates that it relates to a super resolution medium.

Accordingly:

Exhibit III at page 253, Fig. 1 explains track pitch while Exhibit IV illustrates the track pitch for a Blue Ray Disc

Exhibit III at Table 1 on page 256 states a reproduction wavelength of 406 nm, a NA of 0.60, a recording format as land/groove and a modulation code of (1,7) RLL. Further, at page 258 of Exhibit III a recording density of 11 Gbit/in$^2$ is disclosed.

Exhibit IV, on the other hand, at page 26 indicates a recording density of 18 Gbit/in$^2$, a minimum mark length of 0.149 μm and a modulation code of 1-7PP (the same as (1,7) RLL) at 25-Gb BD.

**ANALYSIS**

The storage capacity, Q, for one revolution at radius r from the center of a disc is

$Q = C \times 2\pi r/L$

Where $2\pi r$ is the circumference, while L is the minimum mark length and ***C is a constant determined by the modulation code***. The area S of the data recording region located at radius r is given by

$S = 2\pi r \times P$

Where P is the recording pitch.

Hence, the recording density D for the revolution is given by

$D = Q/S = C \times 2\pi r/L/(2\pi r \times P) = C/(L \times P)$

Assuming the density D1 is the minimum recording density, the minimum mark (i.e., pit) length is L1, the recording pitch is P1 and the constant C1 is associated with Exhibit III, while with regard to the structure of Exhibit IV the density D2, the minimum mark length is L2, the recording pitch is P2 and the constant is C2

$D1 = C1/(L1 \times P1)$ and $D2 = C2/(L2 \times P2)$

***The modulation codes for Exhibit III and Exhibit IV are equal which means that:***

***$C1 = C2$***

Thus, when one substitutes the values from Exhibits III and IV into the foregoing:

D1 = 11 Gbits/in$^2$ (page 258 of Exhibit III)

P1 = 0.40µm – Since the recording scheme attached to Exhibit IV is 'groove recording" (see Table 1) Recording Pitch P2 = Groove Width + Land Width. In contrast, the recording scheme of Exhibit III is "land/groove recording (see Table 1) and Recording Pitch P1 = groove Width = Land Width.

Then:

For the structure of Exhibit IV

D2 = 18 Gbits/in$^2$

P2 = 0.32 µm

L2 = 0.149 µm (see Table 1)

Accordingly:

Since C1 = C2

L1 = C1/(D1 x P1) = D2 x (L2 x P2)/(D1 x P1) = 0.195 µm (well in excess of the minimum mark length L2 = 0.149 µm

> Clearly, therefore, if both the discs of Exhibit III and Exhibit IV are read by the same optical system and L1 is equal to the minimum optical resolution of the optical system, the disk of Exhibit IV has a minimum mark length in excess of the optical resolution of that optical system, yet both the discs of Exhibit III and Exhibit IV can in appropriate contexts exhibit super resolution behaviors.
>
> Note: The recording scheme attached to Exhibit IV is 'groove recording" (see Table 1) Recording Pitch P2 = Groove Width + Land Width. In contrast, the recording scheme of Exhibit 1 is "land/groove recording (see Table 1) and Recording Pitch P1 = groove Width ≒ Land Width

Therefore, Appellants respectfully submit that the Examiner's inference that Tominaga achieves a higher resolution limit than the optical resolution limit of the associated optical system ***does not*** constitute a teaching, disclosure or suggestion that that higher resolution limit originates with signals reproduced from pits shorter than the resolution limit of the optical system as herein claimed. The Tominaga et al disclosure simply does not provide the quantitative measurement basis needed to support the Examiner's position, and, in fact, Tominaga et al appears to teach only that the effective resolution obtained therein is larger than the $\lambda/4NA$ of the original conventional beam (see Tominaga, Col. 4, ln 65 to Col. 5, ln 54 and drawings).

c. **Importance Of Difference Between Prior Art And Present Invention Regarding Direction Of Light Beam Incident On Substrate And Arrangement Of Reproducing Layer**

An alteration of the light-incident-side of the disk from the substrate side as in the Tominaga et al reference to the recording layer side as in the present invention is included in all of the present claims. This feature has been found to be especially effective in reading pits shorter than the optical resolution limit of an associated optical system as herein claimed. In addition, the benefits achievable in the present invention by the irradiation of the light beam from above the reproducing layer are as follows:

The feature that the irradiation of the disc by a light beam is to be from above the reproducing layer in the present invention directly contrary to the teachings of the Tominaga et al reference has been found to be especially effective in reading the claimed pits that are shorter than the optical resolution limit of the associated optical system as discussed above. This is clearly demonstrated by a comparison of Example 1 and the comparative examples of the present specification (see the present specification, page 40, last paragraph through page 41, paragraph 1). In particular, as described at page 28, last paragraph to Page 29, paragraph 2 and Figure 5, the feature (i) is not restrained by the thickness of the reproducing layer and is therefore capable of improved super-resolution capability; and (ii) improves the resolution limit when the layer thickness is unchanged. This is to say that the feature that the pits, corresponding to the recorded data, are shorter than the optical resolution limit of an optical system in the reproducing apparatus is not restrained in the present invention by the thickness of the reproducing layer. The present invention is therefore capable of improved super-resolution capability; and the fact that the irradiation of a light beam comes from above the reproducing layer improves the resolution limit when the layer thickness is unchanged.

Nevertheless, as will appear more fully below, at the time that the present invention was made, those benefits were not known to be attainable without an alteration of the NA of the conventional disk. In particular, as compared with a conventional DVD or the like, at the time that the present invention was made it was extremely difficult to manufacture a Blue ray disk equivalent provided with pits having lengths corresponding to the Blue ray disk resolution. This was because the cutting techniques required for forming pits corresponding to the Blue ray disk were fundamentally different from, and more difficult and time consuming than, those sufficient for a DVD.

d. __Tominaga et al In View Of Jung__

Appellants respectfully submit that the Tominaga et al reference did not teach, disclose or suggest to one of ordinary skill in the art as of the time that the present invention was made either alone or in combination with the Jung reference or the knowledge of one of ordinary skill in the art that in the super resolution context (i) a pit length on a light-incident-surface for recording information should be shorter than the resolution limit of the associated optical system, or (ii) that the light-incident-side of the substrate should be the substrate side adjacent to the reproducing layer.

Appellants respectfully re-assert their belief (noted above) that the Jung reference appears to be clearly and totally inapposite to the present invention. Thus, in Jung the optical recording medium comprises a substrate 1, a reflective layer 2, a charge-generating layer 3, a charge-transferring layer 4, a recording layer 5, and a plurality of spacers 6 defining an air layer 7 between the recording layer 5 and an outer protective layer 8. A laser beam irradiated from above the outer surface of the recording layer 5 having a predetermined wavelength is focused on and absorbed by the charge-generating layer 3 so as the generate a localized charge on the outer surface of the charge-generating layer. The so-generated charge is transferred through the charge-transfer layer 4 and the recording layer 5 to the outer surface of the recording layer 5 so as to color the corresponding charge carrying portion of that surface. Thereafter, readout of the information stored by the charged portions of the outer surface of the layer 5 is accomplished by scanning that surface with a laser beam less intense and having insufficient energy to cause charge generation. More specifically, the charged nature of the surface of the recording layer 5 determines the light transmittance and light reflectance characteristics of the recording layer 5 such that the scanning laser beam allows the recorded information to be recovered. (See Jung at Column 4, line 38 to Column 5, line 7)

Despite the foregoing, the Examiner asserts that:

> Jung teaches the optical data recording medium wherein the recording layer is the light-incident surface and the reproducing layer is provided to face said light incident surface ...such that one of ordinary skill in the art would have recognized the ability to replace the change-transferring (charge-transferring??) materials to lands and pits.

Furthermore, the Examiner concludes that:

> ...taking the teachings of Tominaga et al and Jung as a whole one of ordinary skill in the art would be motivated to combine the teachings of an optical data recording medium and the teachings of the recording and reproducing layer on the surface of the light incident surface for the benefit of an increase in data density and long archival capability

Appellants do not disagree that at the time that the present invention was made an increase in data density and long archival capabilities were sought after goals in the art. However, Appellants respectfully submit that the simply is not any basis within the Examiner's justifications for his outstanding rejections upon which one of ordinary skill in the art at the time that the present invention was made would be lead to combine the teachings of Tominaga et al and Jung. In particular, in Tominaga et al the information is stored on the pitted light-incident surface of the substrate. In Jung, on the other hand, the information is stored in charged areas on the light-incident surface of the recording layer 5, the location in the structure of the reproducing layer of the present invention. However, the outer recording layer 5 of Jung defines areas of more or less transmittance distributed across the area of the outer surface of the layer 5 that are determined during recording by the charges generated in the charge generating layer.

In this way, the Jung reference provides the layer 5 with predetermined areas of varying transmittance, but this varying transmittance is permanent until the charged surface of the layer 5 is discharged completely. Nothing in the Jung reference even remotely suggests or implies that the transmittance of the recording layer 5 is to vary in accordance with the intensity of the scanning reading light beam, heat or any other factor once it is established during the initial recording prior to the discharge of the entire outer surface of the recording layer 5.

Accordingly, Appellants respectfully submit that there is no basis within the four corners of the Examiner's outstanding final rejections upon which one skilled in the art at the time that the present invention was made that would have cause a skilled artisan to substitute a pitted surface for the charge-generating layer 3 in Jung. In Jung the information is both stored on and read from the outer surface of the recording layer 5, not from the charge generating layer 3. In view of this as well as the Examiner's statements at Page 7, lines 11-15, of the currently outstanding Final Official Action, "However, Jung teaches the optical recording medium wherein the recording layer is the light-incident surface ***and the reproducing layer is stacked on the light incident surface***... (Emphasis added), it appears to Appellants that the Examiner has not correctly understood the structure or operation of the Jung reference. Hence, for this reason as well Appellants respectfully submit that the currently outstanding Final Rejections should be withdrawn in response to this Appeal.

In addition, Appellants respectfully submit that the Examiner's determination that the arrangement of elements herein claimed can be obtained by combining cited Tominaga, et al. and Jung references is in error for the reasons discussed below.

The Examiner has acknowledged that Tominaga discloses an optical information recording medium having pits ***to which light is incident from the substrate side*** (i.e., "Tominaga et al. fail to teach the pits are disposed on a light-incident surface thereof (the substrate) and the reproducing layer being provided so as to face said light-incident surface of said substrate. – *Outstanding Final Action, Page 3, lines 6-9.* "Tominaga et al. fail to teach substrate containing pits in a light-incident side thereof, a reproducing layer stacked on the light incident surface, of the substrate, in which the pits are provided and light beam irradiated on the reproducing layer and directed toward the light-incident side of said substrate." – *Outstanding Final Official Action, Page 10, lines 2-5*). On the other hand, the Jung reference discloses an optical data recording medium *(see Figure 1)* wherein in relevant part, the upper (outer) surface of the recording layer 5 is the light incident surface and the location whereat the information is stored. To the extent that there may be a reproducing layer in the Jung reference, it is provided to face the non-light-incident side of the light incident surface (it remains somewhat unclear to Appellants which portion of the Jung structure the Examiner is equating to the reproducing layer – is it the remainder of the recording layer 5 below its outer surface, is it the charge-generating layer 3, is it the reflective layer 2, or is it the substrate 1).

Appellants respectfully submit, therefore, that despite the Examiner's protestations to the contrary, nothing in the either the Tominaga et al reference or the Jung reference discloses, teaches or suggests to one having the normal level of skill in the relevant art at the time that the present invention was made the potential possibility of replacing the change material structure of the Jung reference with lands and/or pits as herein disclosed and claimed, much less the utilization of recording mark lengths smaller than the resolution capacity of the reproducing optical system.

Instead, Appellants respectfully submit that the latter combination as proposed by the Examiner is an exercise in improper hindsight reasoning by the Examiner wherein he attempts to recreate the features of the claims of the present invention from isolated portions of the prior art guided by the teachings of the present specification. Also, in so doing, I appears to Appellants that the Examiner improperly has modified the mode of operation of the Jung reference improperly under the standards quoted above in order to reach the conclusions stated in the outstanding Final Official Action.

The following discussion which views the Examiner's positions in this case from a slightly different perspective is believed to be instructive concerning the erroneous nature of the conclusions drawn by the Examiner in the currently outstanding Final Official Action.. Thus, it will be seen that the Examiner appears to assume that a conventional disc such as that described in (Example 1) of the present application would be recognized by one of ordinary skill in the art at the time that the present invention was made as corresponding to the arrangement disclosed in the cited Tominaga et al reference. If the Examiner's postulated position was correct, however, Appellants respectfully submit that the arrangements according to the independent claims of the present application theoretically could be obtained by applying the arrangement of Jung to a conventional disc, but only assuming that one could overcome the hindsight reasoning problem just mentioned. ***However***, as will appear more fully below, the arrangements according to the independent claims of the present application cannot be so obtained, even if a person skilled in the art could properly apply the arrangement of the Jung reference as modified to utilize pits and lands to a conventional disc. The reasons for this are as follows:

In the actual manufacturing of a substrate, a person of ordinary skill in the art at the time that the present invention was made would form pits on the substrate according to the super-resolution property of a recording medium including the substrate. In the case of the conventional disc as referred to hereinabove, this would mean that pits having a relatively long pit length would be formed in accordance with Fig. 5 of the present application. As a concrete example of this, assume a setting condition requiring a C/N value of 40dB or higher. In such a case, a pit length for a conventional disc such as that just mentioned must be set to approximately 0.2 μm or longer in accordance with Fig. 5 of the present application. Therefore, as shown and discussed in the present specification with respect to Fig. 5, this pit length is longer than the optical resolution limit of the associated optical system (i.e., approximately 0.16 μm).

Even if the above-postulated modification of the Jung reference (i.e., a modified arrangement in which a recording medium has lands (or pits) on the light-incident surface of the substrate that Applicants do not believe is in any way disclosed, taught or suggested in any manner by the art herein relied upon by the Examiner) could or would be applied to a conventional disc having a pit length so determined, the fact remains that conventional arts would not teach, disclose or suggest that such arrangement would make it possible to maintain a high C/N value with a shorter pit length. Therefore, Appellants respectfully submit that a person of ordinary skill in the art at the time that the present invention was made would never set a pit length shorter than the optical resolution limit of the associated optical system, but rather that such an individual would set the pit length as described above with respect to the conventional thinking in the art at the time that the present invention was made directly contrary to the teachings of the present invention. It is Appellants' belief that the Examiner has not even attempted to deal with this issue in the currently outstanding Final Official Action.

A disc obtained in the foregoing manner, however, would not be one having, as is the case of Example 1 of the present application, a pit length shorter than the optical resolution limit of an associated optical system (i.e., in the case of a C/N value equal to or higher than 40dB, the pit length is approximately 0.14 μm or longer), but rather would be one having the same pit length and storage capacity as those of the conventional disc. Therefore, the arrangements according to the independent claims of the present application ("pits ... are shorter than a resolution limit ...") could not be obtained by applying the arrangement of Jung to the conventional disc above. For these reasons, Applicants respectfully submit that their earlier traversal of the Examiner's currently outstanding rejections was fully and completely supported and that the Examiner's currently outstanding rejections/objections to the present application should be withdrawn in response to this submission.

In the foregoing regard as well, Appellants respectfully submit that it should be understood that the arrangement of the present invention is not simply a matter of design choice arrived at on the basis of applying a mode in which reproducing light is incident from an opposite side, as with a Blue-ray Disc (BD) for example, based upon the well known fact that such a mode is capable of improving recording density. The reasons for this are discussed generally at the first full paragraph of Page 21 of the present specification and are further explained as follows:

In a BD arrangement, the recording density is increased due to an increase in NA of the reproducing optical system, which increase in NA is achieved by providing only a short distance from a front side of a disc to an information recording layer (see the following Reference Example).

**Reference Example**

| | Distance from front side of disc to information recording layer | Reproducing light wavelength | NA of reproducing optical system | Recording capacity |
|---|---|---|---|---|
| BD | Approx. 100μm | 405 nm | 0.85 | 25 GB |
| HD-DVD | Approx. 0.6μm | 405 nm | 0.65 | 15 GB |

In other words, the only way to increase the recording density (capacity) of an optical information recording medium that does not have a super resolution property by the method of providing an arrangement like the BD, is to shorten the distance between the front side of the disc and the information recording layer, which as a result increases the NA of the reproducing apparatus. ***However,*** the conventional disc described in Example 1 of the present invention has a same distance from the front side of the disc to the information recording layer as that of the Example 1 disc. Of course, the NA of the reproducing optical system is in both cases is taken as being identically 0.65.

Thus, the reason why the length of a pit that is reproducible by the Example 1 disc can be shortened is completely different from the above Reference Example, i.e., the case where the NA of the reproducing optical system is increased by shortening the distance from the front side of the disc to the information recording layer in an optical information recording medium that does not have a super resolution property.

More specifically, the reason why it is possible to shorten the length of the pit reproducible by the Example 1 disc is because of a unique effect attained by employing the super resolution property of the present invention, in particular by employing an arrangement of "pits which are shorter than a resolution limit of an optical system of a reproducing apparatus".

Therefore, it is respectfully submitted to be unreasonable in the first place to refer to Jung (an optical information recording medium that does not have a super resolution property) or to combine Jung with Tominaga et al. This is because, as demonstrated above, it would at the time that the present invention was made have been extremely difficult for one of ordinary skill in the art by reference to Tominaga et al in view of Jung to arrive at the concept of improving recording density by employing the presently claim arrangement (i.e., an arrangement in which a reproducing layer is provided on a side of the substrate from which reproducing light is incident) and providing shorter pits to the substrate.

Furthermore, Appellants respectfully submit that it would have been difficult for one of ordinary skill in the art at the time that the present invention was made to improve recording capacity without perceiving the difference between the conventional disc described in Example 1 of the present application and the Example 1 disc - that is, the unique effect of the optical information recording medium that has the super resolution property. In addition, as one of ordinary skill in the art at the time that the present invention was made would have been aware, as compared with a conventional DVD or the like, it is extremely difficult with a BD to manufacture a substrate that is provided with pits which have lengths corresponding to the BD. This is because the cutting techniques required for forming the pits corresponding to the BD are fundamentally different from those associated with a DVD.

At the time that the present invention was made, conventional cutting devices were sufficient enough for the DVD's, however, the cutting of the pits that correspond to that of a BD was difficult to achieve by conventional cutting devices, even by the use of a laser having a shorter wavelength (e.g., deep UV). Therefore, there was no other choice but to use EB that requires vacuum processing and takes a long time, or to use a completely new technique (PTM) or the like. Hence, Appellants respectfully submit that it would have been extremely difficult at the time that the present invention was accomplished to obtain a substrate that was provided with pits for super resolution property verification which corresponded to optical system of BD. Accordingly, at the time that the present invention was made, verification of the super resolution property was generally carried out by causing reproducing light to be incident on an information recording layer via a substrate such as a DVD.

Consequently, it will be understood that for those of ordinary skill in the art at the time that the present invention was made in a case where super resolution property was to be verified by a property verification method (corresponding to super resolution property verification for a conventional disc in the present application), a ROM substrate was prepared based on the result of the property verification. That is, when preparing a super resolution property disc having a BD arrangement based on the above result, a person skilled in the art could only conceive that higher N/A resulting from the BD arrangement would increase recording density, but could not expect that the BD arrangement would increase super resolution property. As a result, a person skilled in the art would have prepared a substrate based only on the super resolution property verified by the above property verification method, i.e., a substrate having long pit lengths that do not allow the substrate to fully take advantage of super resolution property yielded by the BD arrangement (a person skilled in the art did not know at the time that the present invention was made that the BD arrangement increases super resolution property and he therefore would keep long pit lengths since he would consider that short pit lengths would not allow the disc to reproduce information).

In other words, when preparing a disc having the BD arrangement based on the result of the above property verification method, a person skilled in the art at the time that the present invention was made would only have prepared a reproduction-only information storage medium having a low recording density.

Accordingly, at the time of the accomplishment of the present invention, the super resolution property, in particular the improvement of recording density, was not known to be attainable by employing (i) an arrangement of "pits which are shorter than a resolution limit of an optical system of a reproducing apparatus", and (ii) an arrangement of providing a reproducing layer on a side of a substrate from which reproducing light is incident, and further the foregoing concepts were not something that could be easily arrived at..

The Examiner's own position taken in response to Applicants' argument that the currently outstanding obviousness rejections are based on improper hindsight reasoning is instructive in this respect. Thus, it will be seen that the Examiner has taken the position that "it must be recognized that any judgment on obviousness is in a sense necessarily a reconstruction based upon hindsight reasoning. But so long as it takes into account only knowledge which was within the level of ordinary skill in the art at the time that the claimed invention was made, and does not include knowledge gained only from the applicants' disclosure, such a reconstruction is proper (see *In re McLaughlin,* 443 F.2d 1392, 170 USPQ 209 (CCPA, 1971)". Appellants respectfully submit that the foregoing discussion clearly demonstrates that the erroneous bases of the Examiner's outstanding arguments have caused him under the standards acknowledged by him with approval to erroneously reject the claims of this application based upon an improper hindsight analysis.

## IX. CONCLUSION

Appellants respectfully submit that the foregoing remarks totally and definitively overcome the Examiner's currently outstanding rejections under 35 USC 103(a) as presented in the currently outstanding FINAL Official Action in the view of the facts and argument of record in the present prosecution. Consequently, Appellants respectfully submit that the instant invention is both novel and inventive over the art relied upon by the Examiner, and respectfully request a decision so holding on this Appeal.

Finally, as mentioned above, although it is not believed that the present submission requires any further fee to secure its consideration by the Patent Office Board of Appeals and Interferences, the Examiner or other appropriate officer, of the United States Patent and Trademark Office, the undersigned hereby authorizes the charge of any such fee that may be deemed to be due, appropriate or otherwise required, or the credit of any overpayment, to the deposit account of the undersigned, Deposit Account **04-1105** .

Respectfully submitted,

Date: August 16, 2010

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## APPENDICES

## CLAIMS APPENDIX

1. (Rejected) An optical data recording medium, in which irradiation of a light beam is used for reproducing recorded data, comprising:

    a substrate having pits disposed on a light incident surface thereof, corresponding to the recorded data, which are shorter than a resolution limit of an optical system of a reproducing apparatus which reproduces that optical data recording medium; and

    a reproducing layer for improving the resolution of optical signals from said pits and passing said improved resolution optical signals from said pits to said optical system of said reproducing apparatus in a form reproducible by said reproducing apparatus, the reproducing layer being provided so as to face said light-incident surface of said substrate.

2. Cancel without prejudice.

3. (Rejected) The optical data recording medium as set forth in Claim 1, wherein:

    the reproducing layer is made of a material whose transmittance changes in accordance with temperature.

4. (Rejected) The optical data recording medium as set forth in Claim 1 wherein:

    at least a part of a light-incident surface of the reproducing layer is exposed to air.

5. (Rejected) The optical data recording medium as set forth in Claim 1 further comprising:

a light absorption layer for converting an incident light beam directed toward said light incident surface of said substrate to heat, the light absorption layer being contiguous to the reproducing layer.

6. (Rejected) The optical data recording medium as set forth in Claim 1 further comprising:

a reflective layer for reflecting an incident light beam directed toward said light incident side of said substrate, the reflective layer being provided between said light incident side of said substrate and said reproducing layer.

7. (Rejected) The optical data recording medium as set forth in Claim 1 wherein:

the reproducing layer is made of a metal oxide.

8. (Rejected) The optical data recording medium as set forth in Claim 7, wherein:

the reproducing layer is made of a zinc oxide.

9. (Rejected) The optical data recording medium as set forth in Claim 5, wherein:

the light absorption layer is made of one of silicon, germanium and an alloy of silicon and germanium.

10. (Rejected) An optical data recording medium, in which irradiation of a light beam is used for reproducing recorded data, comprising:

a substrate having a light incident surface containing pits, corresponding to the recorded data, which are shorter than a resolution limit of an optical system which reproduces the optical data recording medium;

a reproducing layer, stacked on the light incident surface of the substrate in which the pits are provided, the reproducing layer having a changeable transmittance with respect to an irradiated light beam irradiated on the reproducing layer and directed toward said light incident surface of said substrate, the changeable transmittance being changeable in accordance with an intensity distribution of the light beam irradiated on the reproducing layer; and

a reflective surface, provided between the substrate and the reproducing layer, for reflecting a light beam that has passed through the reproducing layer.

11. (Rejected) The optical data recording medium as set forth in Claim 10, further comprising:

a reflective layer provided between the substrate and the reproducing layer, and including the reflective surface.

12. (Rejected) The optical data recording medium as set forth in Claim 10, further comprising:

a light absorption layer, provided between the substrate and the reproducing layer, for converting, to heat, the light beam irradiated thereon.

13. (Rejected) The optical data recording medium as set forth in Claim 10, wherein:
at least a part of that surface of the reproducing layer which is a reverse surface to the surface facing the substrate is exposed to air.

14. Canceled without prejudice.

15. Canceled without prejudice.

16. Canceled without prejudice.

17 (Rejected) A reproducing method of an optical data recording medium in which irradiation of a light beam is used for reproducing data recorded in the optical data recording medium,
said optical data recording medium including:
a substrate having a light incident surface containing pits, corresponding to recorded data, which are shorter than a resolution limit of an optical system of a reproducing apparatus which reproduces the optical data recording medium; and

a reproducing layer for improving the optical resolution of optical signals from said pits and passing said improved resolution optical signals to said optical system of said reproducing apparatus in a form reproducible by said reproducing apparatus,

the reproducing layer being provided so as to face said light-incident surface of the substrate,

said reproducing method comprising the step of:

irradiating the light beam from above the reproducing layer to the light incident surface side of said substrate so as to reproduce the pits.

18. (Rejected) A reproducing method of an optical data recording medium in which irradiation of a light beam is used for reproducing data recorded in the optical data recording medium,

said optical data recording medium including:

a substrate containing pits in a light incident side thereof, corresponding to the recorded data, which are shorter than a resolution limit of an optical system of a reproducing apparatus which reproduces the optical data recording medium;

a reproducing layer stacked on the light incident surface of the substrate in which the pits are provided, the reproducing layer having a changeable transmittance with respect to an irradiated light beam irradiated on the reproducing layer and directed toward said light incident side of said substrate, the changeable transmittance being changeable in accordance with an intensity distribution of the light beam irradiated on the reproducing layer; and

a reflective surface, provided between the substrate and the reproducing layer for reflecting a light beam that has passed through the reproducing layer,

said reproducing method comprising the step of:

reproducing said recorded data by irradiating a light beam onto said optical data recording medium from above the reproducing layer.

# EVIDENCE APPENDIX

**Exhibit I** **US Patent No. 5,569,517 dated October 29, 1996 (Tominaga et al)**

**Exhibit II** **US Patent No. 5,516,568 dated May 14, 1996 (Jung)**

**Exhibit III** **Proc. SPIE 4342,252 (2002) 50-mm CAD-MSR Disk System with Blue Laser,Y, Murakami, et al**

**Exhibit IV** **"New Anatomy of Next –generation Optical Discs: In-depth Analysis (with partial English language translation of relevant sections)**

## RELATED PROCEEDINGS APPENDIX

**Not Applicable**

US005569517A

# United States Patent [19]

Tominaga et al.

[11] Patent Number: 5,569,517

[45] Date of Patent: Oct. 29, 1996

[54] OPTICAL INFORMATION MEDIUM

[75] Inventors: Junji Tominaga, Nagano; Susumu Haratani, Chiba; Ryo Inaba; Tsuneo Kuwahara, both of Nagano, all of Japan

[73] Assignee: TDK Corporation, Tokyo, Japan

[21] Appl. No.: 462,286

[22] Filed: Jun. 5, 1995

[30] Foreign Application Priority Data

Jun. 23, 1994 [JP] Japan .................................... 6-164577

[51] Int. Cl.$^6$ .................................................... B32B 3/00

[52] U.S. Cl. ........................ 428/64.1; 428/64.2; 428/64.4; 428/64.5; 428/64.6; 428/913; 430/270.1; 430/270.11; 430/270.12; 430/270.13; 430/495.1; 430/945; 369/275.2; 369/283; 369/288

[58] Field of Search .................................. 428/64.1, 64.2, 428/64.4, 64.5, 64.6, 457, 913; 430/270, 495, 945, 270.1, 270.11, 270.12, 270.13; 369/275.2, 283, 288

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| 5,418,030 | 5/1995 | Tominaga | 428/64.1 |

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|---|---|---|
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| 3264611 | 4/1993 | Japan . |
| 3264609 | 4/1993 | Japan . |
| 3249511 | 4/1993 | Japan . |

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Optical Storage Read–Out of Nonlinear Disks; Bouwhuis et al.; pp. 3766–3768; Applied Optics; vol. 29, No. 26; 10 Sep. 1990.

New Opto–Magnetic Disk, Irister; Miyaoka; pp. 393–398; Solid Phisics; vol. 26; No. 6 (1991).

*Primary Examiner*—Patrick Ryan
*Assistant Examiner*—Elizabeth Evans
*Attorney, Agent, or Firm*—Watson Cole Stevens Davis, PLLC

[57] ABSTRACT

An optical information medium has on a substrate (2) with information-carrying pits (21), a light transmittance control layer (3) including a lower dielectric layer (31), a mask layer (32) and an upper dielectric layer (33). The mask layer has an original state before irradiation of reading light. Upon irradiation of a reading light beam to define a beam spot, the mask layer undergoes a crystal-to-crystal transition in a region (H) of the beam spot depending on the intensity distribution of the beam spot. Multiple reflection condition changes in the transition portion so that the beam spot contributing to read-out is limited to the transition or transition-free region (H or L). The transition temperature is in the range of 200° to 450° C. The mask layer returns to the original state after passage of the beam spot. The invention is also applicable to an optical recording medium having a recording layer above or below the transmittance control layer.

14 Claims, 5 Drawing Sheets

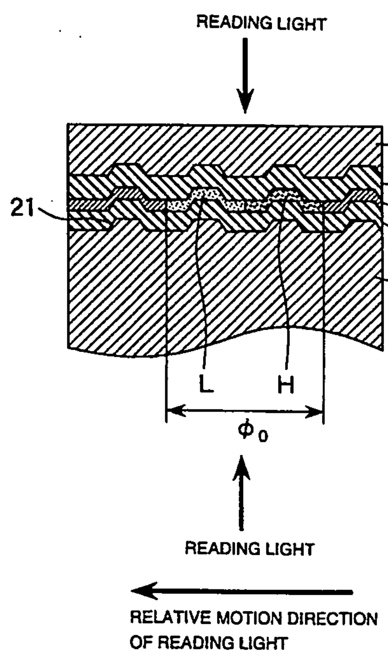


FIG. 1

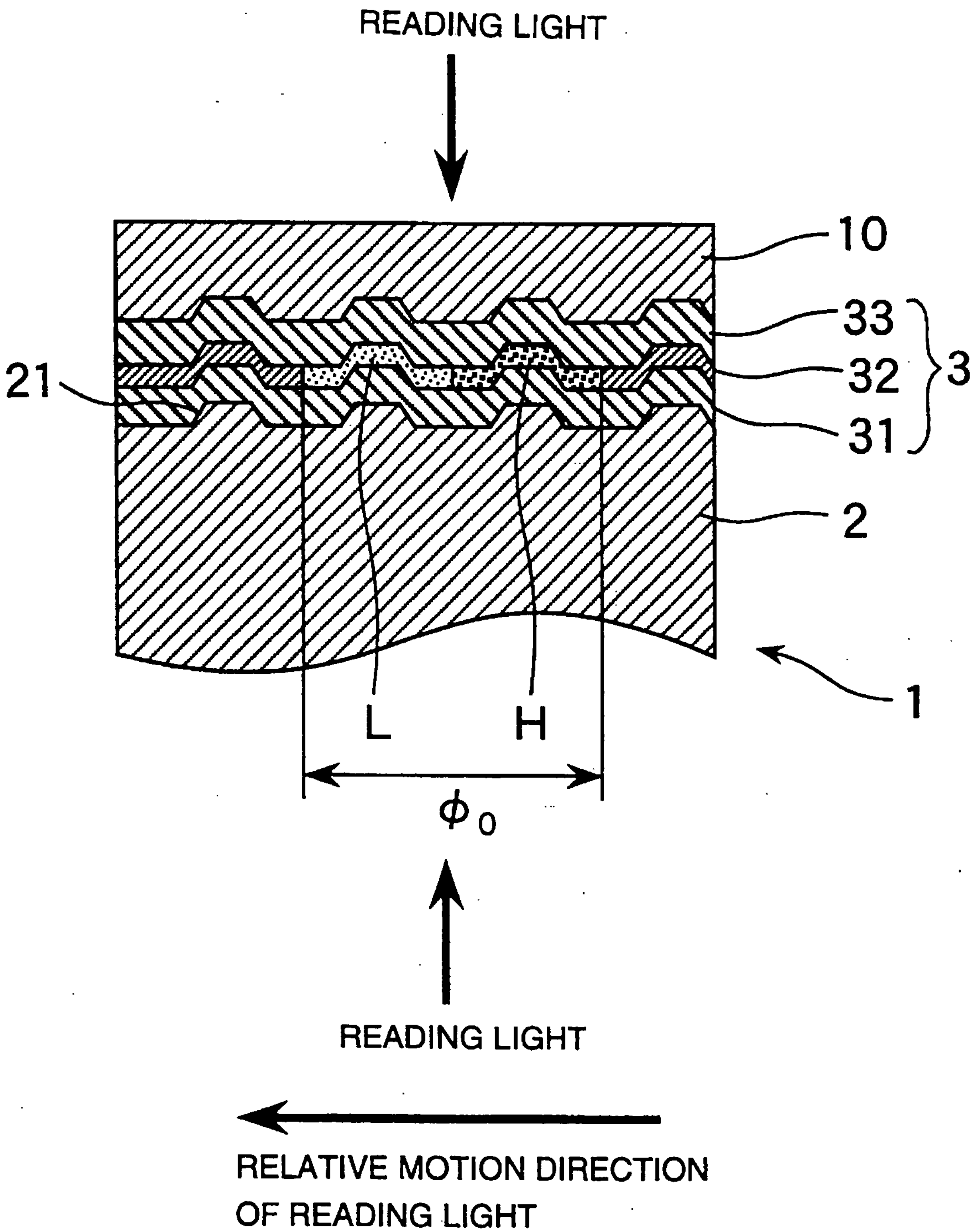

READING LIGHT
10
33
32
3
31
21
2
1
L
H
$\phi_0$
READING LIGHT
RELATIVE MOTION DIRECTION
OF READING LIGHT

FIG. 2

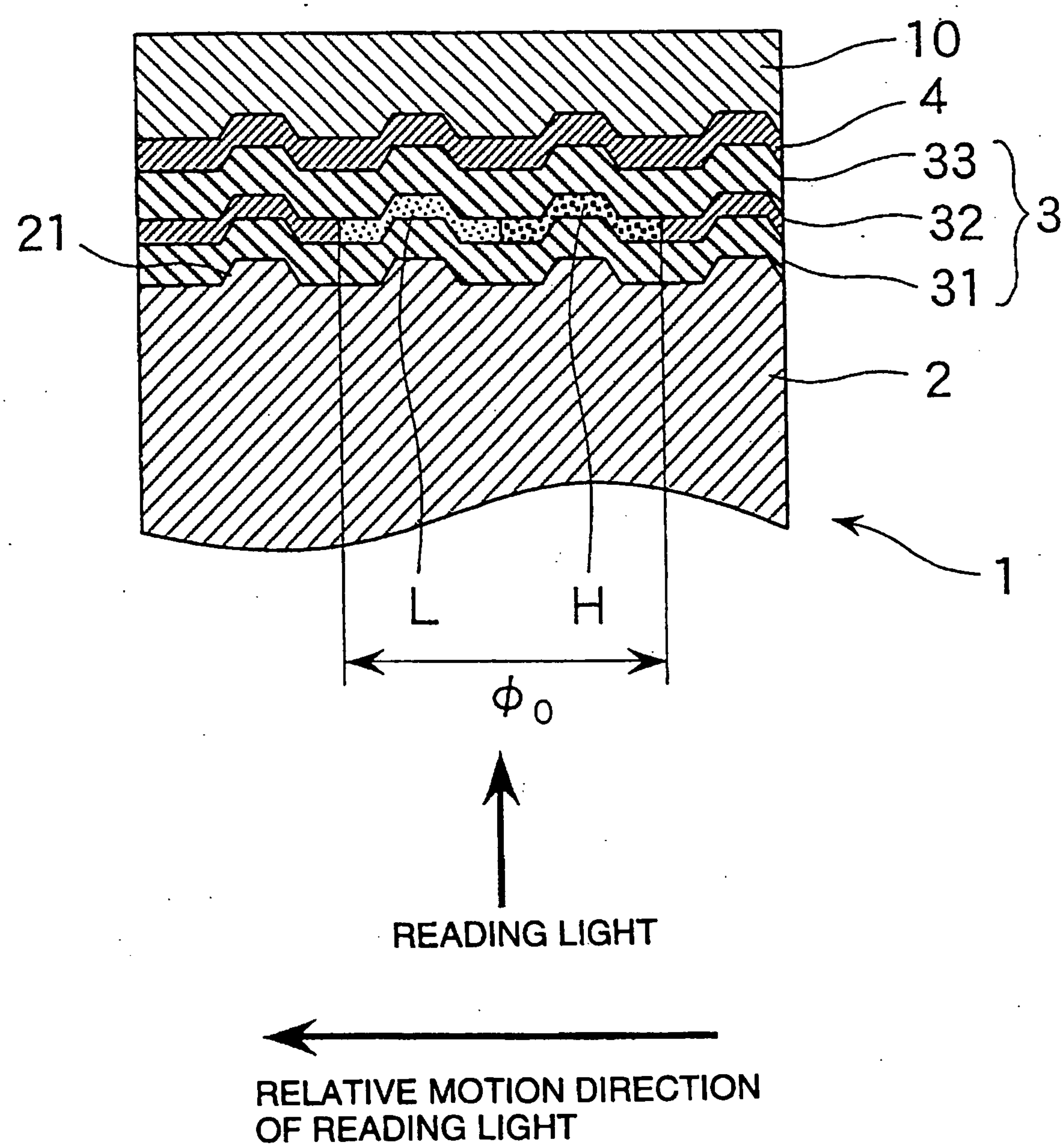
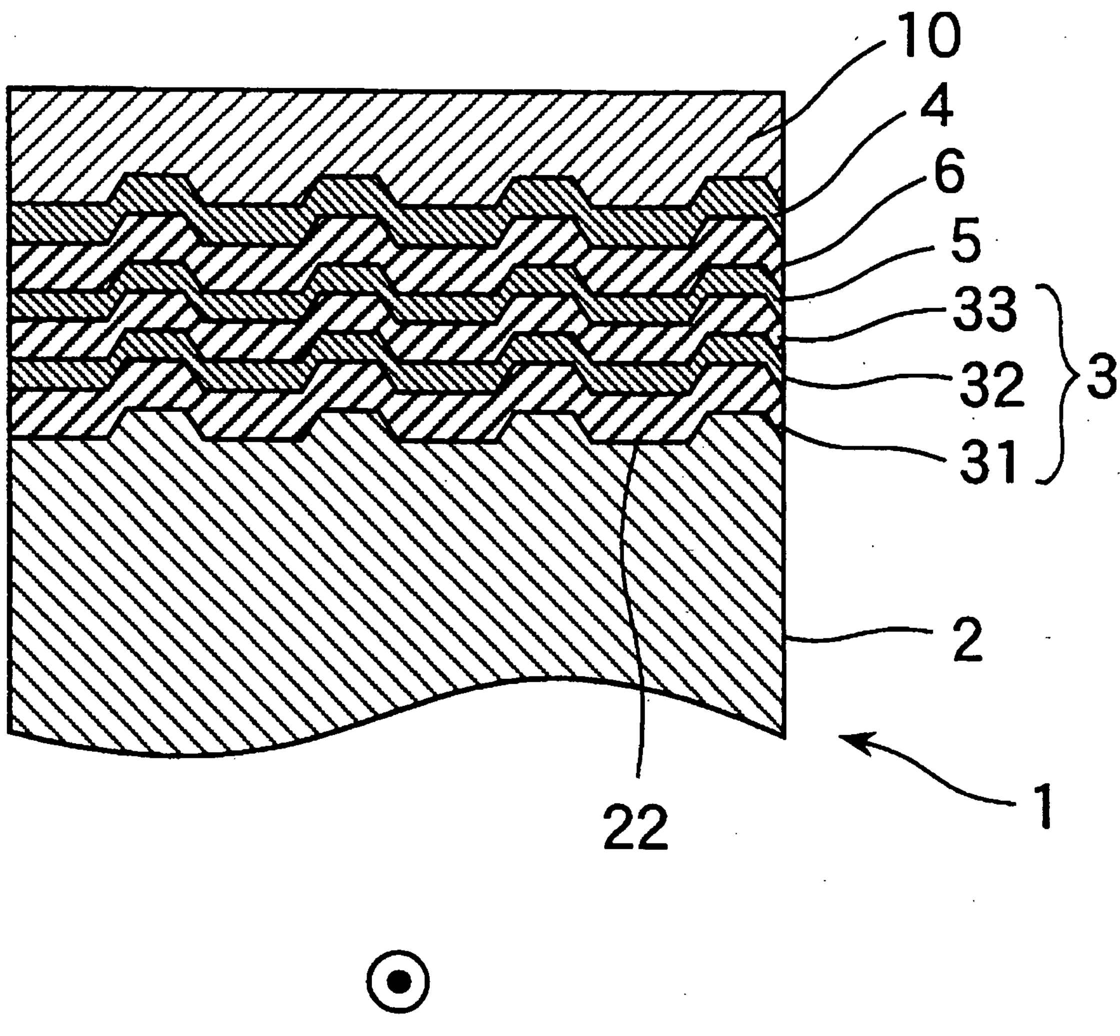

10
4
33
32
3
31
21
2
1
L
H
$\phi_0$
READING LIGHT
RELATIVE MOTION DIRECTION
OF READING LIGHT

FIG.3




RELATIVE MOTION DIRECTION OF RECORDING AND READING LIGHT

FIG. 4

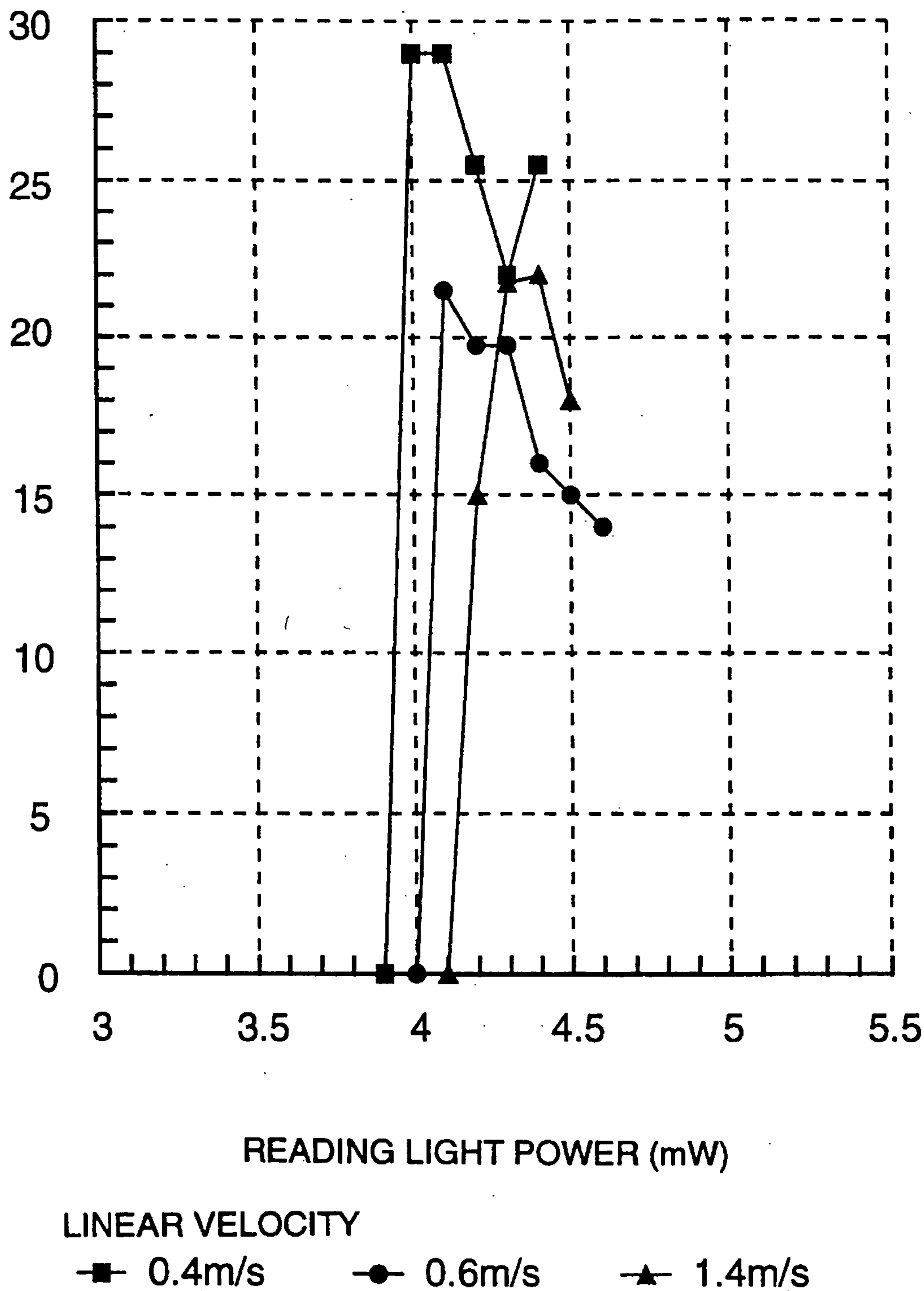

30
25
20
15
10
5
0
3
3.5
4
4.5
5
5.5
READING LIGHT POWER (mW)
LINEAR VELOCITY
0.4m/s
0.6m/s
1.4m/s

FIG. 5

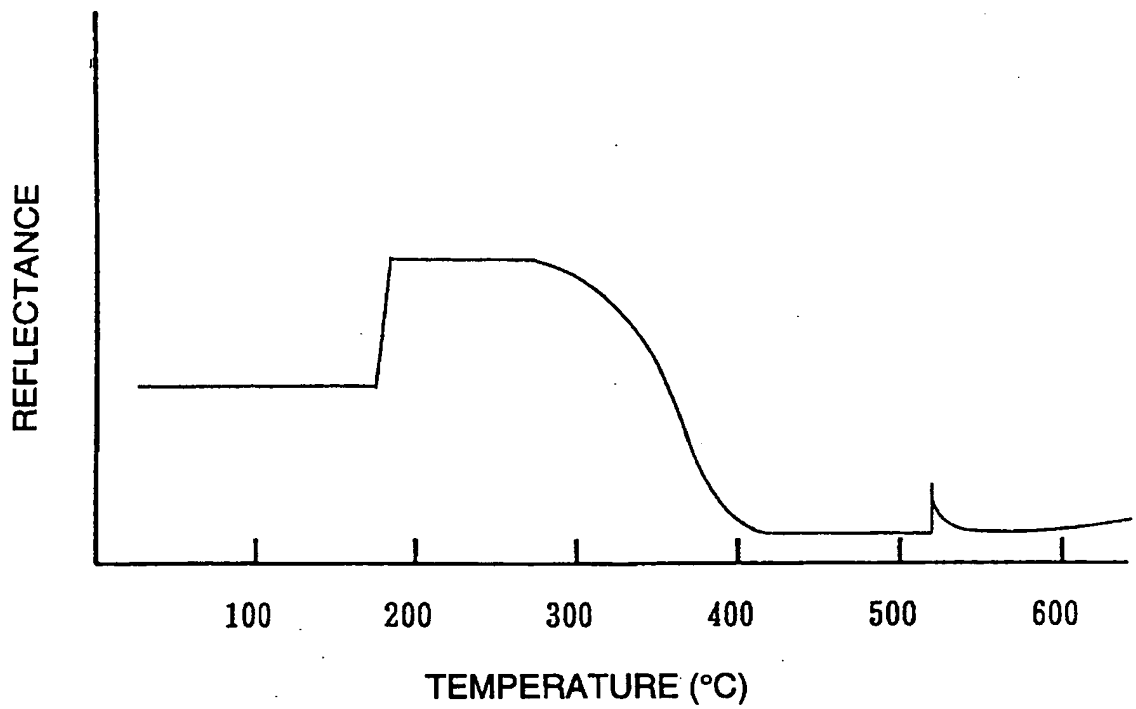
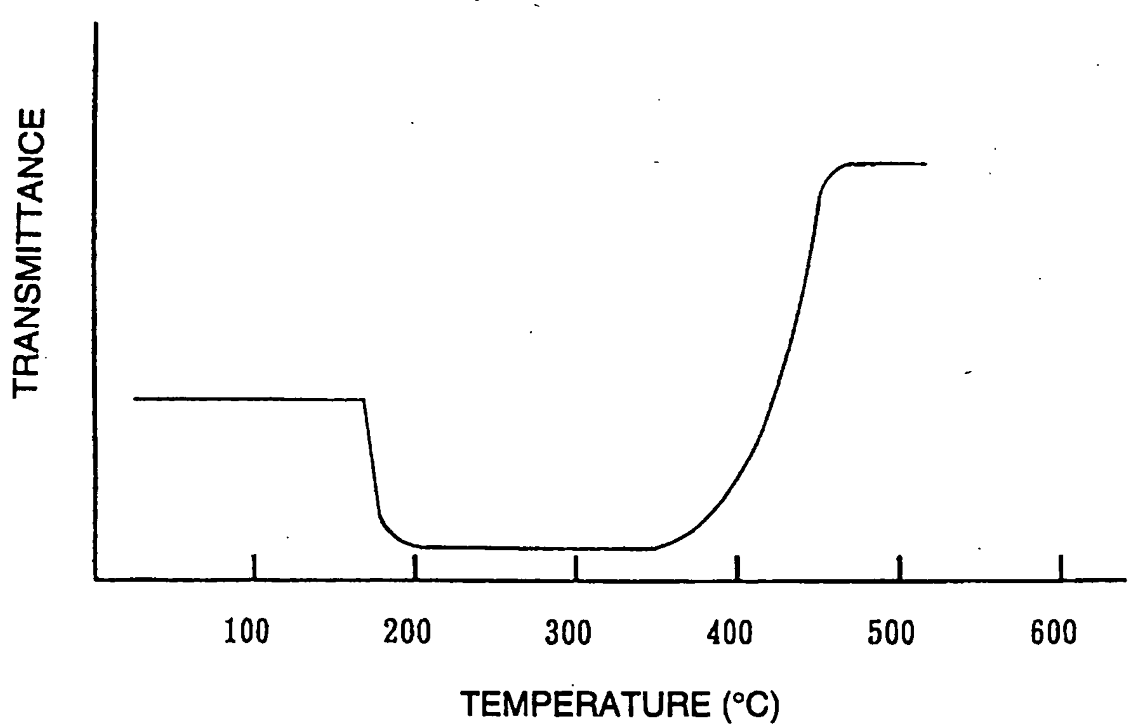

REFLECTANCE
100
200
300
400
500
600
TEMPERATURE (°C)

FIG. 6


TRANSMITTANCE
100
200
300
400
500
600
TEMPERATURE (°C)

# OPTICAL INFORMATION MEDIUM

## TECHNICAL FIELD

This invention relates to an optical information medium having a high recording density.

## BACKGROUND ART

Optical information media include read only optical discs as typified by compact discs, erasable optical recording discs such as magneto-optical recording discs and phase change type recording discs, and write-once optical recording discs using organic dyes as the recording material.

In general, optical information media have a high information density as compared with magnetic recording media. It is now required to further increase the information density for processing a very large quantity of information as in picture processing. Information density per unit area can be increased in two ways, by reducing a track pitch and by reducing the distance between record marks or phase pits for achieving an increased linear density. However, as the track density or linear density is increased relative to a beam spot of reading light, C/N of read signals becomes poor and eventually signal read-out becomes impossible. Resolution upon signal read-out is determined by the diameter of a beam spot. More particularly, when signals are read out through an optical system having an objective lens with a numerical aperture NA using reading light having a wavelength 1, a spatial frequency 2NA/1 becomes a limit of read-out. Therefore, for improving the C/N and resolution of read signals, it is effective to reduce the wavelength of reading light and to increase NA. Many research works have been carried out in this regard, but there still remain many technical problems to be solved.

JP-A 96926/1990 or U.S. Pat. No. 5,153,873 proposes a recording carrier having a layer of non-linear optical material for achieving super-resolution. This non-linear optical material changes its optical properties by incident radiation. Such changes include changes of transmittance, reflectance, and refractive index as well as deformation of the layer. When a high intensity beam is irradiated to the information-carrying surface through the non-linear optical material layer, smaller areas of the object can be read out by these optical changes.

The above-cited patent reference discloses a bleaching layer as one example of the non-linear optical material layer. The bleaching layer increases transmittance with the increasing intensity of incident radiation. Exemplary materials used in the bleaching layer are gallium arsenide, indium arsenide and indium antimony. However, since the layer of such non-linear optical material requires the absorption center to be entirely excited, reading light must have a high energy density, imposing difficulty to material and medium design.

The above-cited patent reference also discloses use of a phase change material as the non-linear optical material. Exemplary phase change materials are GaSb and InSb. The patent reference describes: "It has been found that the complex refractive index of this type of material is temperature dependent to such an extent that, even in the case of irradiation with an intensity remaining below the level at which the conversion from amorphous to crystalline or conversely occurs, there is a sufficiently large variation of the complex refractive index to enable layers of these materials to be used as non-linear layers in the sense of the present invention." Although the reason why such a change



of complex refractive index occurs is not described in the patent reference, it is presumed that this change of complex refractive index involves a crystal-to-crystal transition of the non-linear optical material layer. In this case, since there is no need to melt the non-linear optical material, reading light of low power can be used. However, GaSb has a crystal-to-crystal transition temperature at a low temperature of about 30° C. or a high temperature of about 590° C. and InSb has a crystal-to-crystal transition temperature at a low temperature of about 150° C. or a high temperature of about 500° C. When the higher transition temperature of these phase change materials is utilized, reading light of high power must be used, giving rise to problems as mentioned above. On the other hand, when the lower transition temperature of these phase change materials is utilized, reading light of low power can be used. However, stable read-out is substantially impossible with GaSb because the transition temperature is extremely low. Problems also arise with InSb. Since the transition temperature is relatively low, the non-linear optical material layer is slow in cooling rate. Heat accumulates in the proximity of a mask layer to enlarge the apparent diameter of a beam spot, adversely affecting super-resolution read-out.

JP-A 89511/1993, 109117/1993, and 109119/1993 disclose an optical disc comprising a transparent substrate having formed therein phase pits which can be optically read out and a material layer thereon which changes its reflectance with temperature. This material layer is provided for achieving higher resolution beyond the limit determined by the reading light wavelength 1 and objective lens numerical aperture NA through approximately the same function as the non-linear optical material layer of JP-A 96926/1990. However, this material layer requires reading light of higher power because a crystal-to-liquid or amorphous-to-liquid change is necessary for read-out.

## SUMMARY OF THE INVENTION

Therefore an object of the present invention is to provide an optical information medium from which high density information can be read out using reading light of low power in a stable manner without resorting to the conventional means of reducing the wavelength of reading light or increasing the numerical aperture of an objective lens in optical read system.

According to a first aspect of the present invention, there is provided an optical information medium comprising a substrate having pits formed on one surface for carrying information. A light transmittance control layer including a lower dielectric layer, a mask layer and an upper dielectric layer is disposed on the substrate surface. The mask layer has an original state before irradiation of reading light. The mask layer undergoes a crystal-to-crystal transition upon irradiation of reading light to introduce a change in the reflectance of reading light. The crystal-to-crystal transition takes place at a temperature of 200° to 450° C. The mask layer returns to the original state after irradiation of reading light. Preferably the medium further includes a reflecting layer above or below the light transmittance control layer.

According to a second aspect of the present invention, there is provided an optical information medium comprising a substrate, a light transmittance control layer on a surface of the substrate including a lower dielectric layer, a mask layer and an upper dielectric layer, and a recording layer above or below the light transmittance control layer. The mask layer has an original state before irradiation of reading

light. The mask layer undergoes a crystal-to-crystal transition upon irradiation of reading light to introduce a change in the reflectance of reading light. The crystal-to-crystal transition takes place at a temperature of 200° to 450° C. The mask layer returns to the original state after irradiation of reading light. Preferably the medium further includes a reflecting layer. The recording layer is interposed between the light transmittance control layer and the reflecting layer. Alternatively, the light transmittance control layer is interposed between the recording layer and the reflecting layer.

The recording layer may be either of phase change type or of magneto-optical type whereby the optical information medium constitutes an optical recording medium.

In both the first and second embodiments, the mask layer preferably contains silver (Ag) and zinc (Zn) as main components.

In another preferred embodiment, the mask layer contains tellurium (Te) and germanium (Ge) as main components.

In a further preferred embodiment, the mask layer contains elements A, B, and C wherein A is silver (Ag) and/or gold (Au), B is antimony (Sb) and/or bismuth (Bi), and C is tellurium (Te) and/or selenium (Se). The mask layer may further contain indium (In). The mask layer may further contain at least one element M selected from the group consisting of Ti, Zr, Hf, V, Nb, Ta, Mn, W, and Mo.

Further preferably in both the first and second embodiments, the mask layer has an original volume before irradiation of reading light, the mask layer changes its volume as a result of the crystal-to-crystal transition of the mask layer upon irradiation of reading light, and the mask layer returns to the original volume after irradiation of reading light.

## ADVANTAGES

Information is read out from the optical information medium of the invention by directing reading light to the mask layer to define a beam spot whereupon the diameter of the beam spot which contributes to read-out is reduced, thereby increasing resolution of read-out. Since the mask layer is formed of a material which undergoes a crystal-to-crystal transition below a predetermined temperature (450°C.), reading light of low power can be used. Then less burden is imposed on the components of the medium, which ensures a higher degree of freedom in selecting a material for the respective components and better repetition durability for the medium. Since the mask layer material undergoes a crystal-to-crystal transition above a predetermined temperature (200°C.), stable read-out is ensured. Since the mask layer undergoes crystal-to-crystal transition by being heated by reading light, the benefits of the invention little depend on the wavelength of reading light.

## BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the invention will be better understood from the following description taken in conjunction with the accompanying drawings.

FIG. 1 is a schematic circumferential cross-sectional view of a portion of an optical information medium according to a first embodiment of the invention.

FIG. 2 is a view of the optical information medium of FIG. 1 having a reflecting layer.



FIG. 3 is a schematic radial cross-sectional view of a portion of an optical information medium according to a second embodiment of the invention.

FIG. 4 is a graph showing the C/N ratio of an optical information medium relative to the power of reading light.

FIG. 5 is a graph showing the reflectance of a medium relative to the temperature of the mask layer.

FIG. 6 is a graph showing the transmittance of a medium relative to the temperature of the mask layer.

## BEST MODE FOR CARRYING OUT THE INVENTION

Referring to FIG. 1, there is schematically illustrated a portion of an optical information medium according to the first embodiment of the invention. The optical information medium generally designated at **1** is a read-only optical information medium and includes a substrate **2** having pits **21** formed on one surface for carrying information. A light transmittance control layer **3** is disposed on the substrate surface. The light transmittance control layer **3** includes a lower dielectric layer **31**, a mask layer **32**, and an upper dielectric layer **33** from the bottom in the described order. A protective layer **10** is disposed on the light transmittance control layer **3**. The lower dielectric layer **31** is in contact with the substrate **2** and the upper dielectric layer **33** is in contact with the protective layer **10**.

Referring to FIG. 2, there is schematically illustrated a portion of another optical information medium according to the first embodiment of the invention. This read-only optical information medium **1** has the same construction as FIG. **1** except that a reflective layer **4** is interposed between the light transmittance control layer **3** and the protective layer **10**.

In the optical information medium of the construction illustrated in FIG. **1**, reading light may be irradiated to the medium either through the substrate **2** or from the upper dielectric layer **33** side as shown by an upward or downward arrow. In the optical information medium of the construction illustrated in FIG. **2**, reading light is irradiated to the medium through the substrate **2** as shown by an upward arrow. It is understood that the embodiment of FIG. **2** may be modified such that the reflecting layer **4** is interposed between the light transmittance control layer **3** and the substrate **2**, and then reading light is irradiated from the upper dielectric layer **33** side.

Where reading light is irradiated through the substrate, the substrate should be formed of a material which is substantially transparent to the reading light, for example, resins and glass. Resins are preferred for ease of handling and low cost. Useful resins include acrylic resins, polycarbonate resins, epoxy resins, and polyolefin resins. The pits formed on the substrate surface may be ridges or recesses (more generally, of convex or concave configuration) allowing information to be read out by utilizing a phase difference. The shape and size of the substrate are not critical although it is generally of disc shape and has a diameter of about 50 to about 360 mm and a thickness of about 0.2 to about 3 mm. The substrate may be provided on the surface with grooves or the like for tracking and addressing purposes.

Normally the mask layer has a certain crystalline state, often referred to as an original state, before irradiation of reading light.

The reading light to be irradiated to the optical information medium **1** is typically a laser beam which is focused on nearly the mask layer **32**. Then the reading light or laser

beam defines a beam spot having an approximately Gaussian intensity profile in a plane of the mask layer. More specifically, the beam spot of reading light has such an intensity profile that intensity declines from near the center toward the periphery. Then, by using reading light of an appropriate power, the mask layer can be partially heated only near the center of the beam spot to a temperature necessary for a crystal-to-crystal transition to occur. It is understood in this regard that since the beam spot of reading light is moving relative to the optical information medium **1** as shown by a horizontal arrow in FIG. **1**, the region of the higher temperature is generally the region that is retained within the beam spot for the longer time. In the embodiments shown in FIGS. **1** and **2**, the focused beam spot of reading light has a diameter $f_0$, the region of the mask layer **32** which has undergone a crystal-to-crystal transition is designated at H, and the region of the mask layer **32** which is within the beam spot, but remains below the transition temperature is designated at L.

Since a crystal-to-crystal transition causes the mask layer to change its complex part of refractive index and also its real part of refractive index, multiple reflection conditions change in the transition region. By properly selecting the composition of the mask layer, and the thickness and refractive indices of respective layers of the light transmittance control layer, the reflectance of reading light can be either increased or decreased in the region H. Where the reflectance of reading light is increased in the region H in the medium shown in FIG. **1** or where the reflectance of reading light is decreased in the region H in the medium shown in FIG. **2**, the resolution of read-out is almost the same as in the situation where a beam spot having an area corresponding to the region H is irradiated for read-out. This means that since the mask layer serves to reduce the beam spot, resolution can be increased without reducing the wavelength of reading light or increasing the numerical aperture of an objective lens in optical read-out system. Where the reflectance of reading light is decreased in the region H in the medium shown in FIG. **1** or where the reflectance of reading light is increased in the region H in the medium shown in FIG. **2**, the resolution of read-out is almost the same as in the situation where a beam spot having an area corresponding to the region L is irradiated for read-out, also achieving high resolution.

After the beam spot of reading light has passed over, the mask layer cools down and returns to the original state, that is, the crystalline phase that the mask layer had before irradiation of reading light. Then the complex part of refractive index and real part of refractive index also return to their original values (or values before irradiation of reading light). After passage of the beam spot, the reflectance of the mask layer to reading light quickly comes back to the original level. This minimizes the crosstalk noise between adjacent pits.

According to the present invention, the mask layer undergoes a crystal-to-crystal transition at a temperature in the range of 200° to 450° C., preferably 200° to **400**° C. If the transition temperature is below 200° C., the mask layer has a slower cooling rate to allow heat to accumulate in the upper and lower dielectric layers. As a result, the apparent diameter of a beam spot becomes larger, which is disadvantageous for super-resolution read-out. If the transition temperature is above 450° C., reading light of higher power is necessary. It is noted that the mask layer may have two or more crystal-to-crystal transition temperatures as long as the transition temperature at which the above-mentioned effect is derived is available within the above-defined range.

In one preferred embodiment wherein the mask layer has an original volume before irradiation of reading light, the mask layer changes its volume as a result of the crystal-to-crystal transition mentioned above. The mask layer substantially returns to the original volume after irradiation of reading light. Such a volume change taking place in the crystal-to-crystal transition region leads to a larger change of reflectance of reading light and hence, a higher C/N ratio. It is noted that this volume change may be either a volume increase or a volume decrease.

Although the optimum thickness of the mask layer varies with a particular material, it is preferably about 3 to about 100 nm thick, more preferably about 5 to about 50 nm thick. A too thin mask layer would be insufficient for masking purpose whereas a too thick mask layer would cause a drop of light transmittance which will reduce the quantity of read-out signal returned, resulting in a drop of C/N ratio.

The mask layer is formed of a material which can undergo crystal-to-crystal transition. Preferably it contains silver (Ag) and zinc (Zn) as main components; or tellurium (Te) and germanium (Ge) as main components; or elements A, B, and C wherein A is silver (Ag) and/or gold (Au), B is antimony (Sb) and/or bismuth (Bi), and C is tellurium (Te) and/or selenium (Se).

In the embodiment wherein the mask layer contains silver (Ag) and zinc (Zn) as main components, $\beta$-$\zeta$ transition is utilized. The ratio Zn/(Ag+Zn) is preferably 40 to 60 at%, more preferably 45 to 50 at%. With higher or lower Zn ratios, the transition temperature would not fall in the above-defined range. As long as a transition temperature is available within the above-defined range, compositions wherein at least one of Cu and Au substitutes for at least part of silver and compositions wherein Cd substitutes for at least part of zinc, for example, Ag—Cd are also acceptable.

In the embodiment wherein the mask layer contains tellurium (Te) and germanium (Ge) as main components, the ratio Ge/(Te+Ge) is preferably 20 to 60 at%, more preferably 40 to 50 at%. With higher or lower Ge ratios, the transition temperature would not fall in the above-defined range. Substitution of Se for part of Te and substitution of at least one of Si and Bi for part of Ge are acceptable insofar as the degree of substitution is below 50 at %.

In the embodiment wherein the mask layer contains elements A, B, and C as defined above, there are generally present an $ABC_2$ phase such as $AgSbTe_2$ phase and a B phase such as Sb phase. Preferably the mask layer further contains indium. Indium bonds with C and is present as an In-C phase, typically In-Te phase. The In-C phase contains In and C substantially in a ratio of 1:1. All the $ABC_2$, B, and In-C phases are crystalline. The presence of respective phases is ascertainable by observation under a transmission electron microscope and electron probe microanalysis (EPMA). The mask layer may further contain at least one element M selected from the group consisting of Ti, Zr, Hf, V, Nb, Ta, Fin, W, Mo, Si, and Sn. Element M is effective for improving stability in repetitive read-out, that is, reliability. Among these, vanadium and titanium, especially vanadium are more effective for improving reliability. Preferably at least one of vanadium and titanium, especially vanadium occupies 80 at % or more of the entire elements M, most preferably 100 at %. Besides, inclusion of copper, nickel, zinc, iron, oxygen, nitrogen, and carbon as trace impurities is acceptable although the total content of these impurities should preferably be less than 0.05 at % of the mask layer.

It is believed that in the mask layer containing elements A, B, and C, a crystal-to-crystal transition occurs as a change

of balance between $ABC_2$ and B phases. It was empirically found in X-ray diffractometry that in excess of the transition temperature (about 320°C.), the peak of $ABC_2$ phase increased its intensity while the peak intensity of B phase became low. The reason is that the B phase is accommodated by the $ABC_2$ phase because the $ABC_2$ phase is more stable than the B phase.

This mask layer can be represented by the formula:

$$A_aB_bC_cIn_dM_e$$

wherein A is silver and/or gold, B is antimony and/or bismuth, C is tellurium and/or selenium, In is indium, M is at least one of Ti, Zr, Hf, V, Nb, Ta, Mn, W, and Mo, and letters a, b, c, d, and e representing atomic ratios of the associated elements are in the range: $3.0 \leqq a \leqq 13.0$, $45.0 \leqq b \leqq 87.0$, $8.0 \leqq c \leqq 34.0$, $2.0 \leqq d \leqq 8.0$, and $0 \leqq e \leqq 5.0$, preferably in the range: $6.0 \leqq a \leqq 10.0$, $50 \leqq b \leqq 65$, $15 \leqq c \leqq 32$, $3.0 \leqq d \leqq 6.0$, and $0 \leqq e \leqq 3.0$, provided $a+b+c+d+e=100$. If any of a to e is outside the range, no crystal-to-crystal transition would occur or the mask layer would slowly return to the original state, restraining super-resolution read-out. Silver is preferred as element A. Preferably at least 56 at %, more preferably at least 80 at % of element A is silver. Most preferably silver is solely used as element A. If a Au percentage in element A is too high, growth of $ABC_2$ phase at about the transition temperature would be inhibited, resulting in a smaller change of refractive index. Antimony is preferred as element B. Preferably at least 50 at %, more preferably at least 80 at % of element B is antimony. Most preferably antimony is solely used as element B. Tellurium is preferred as element C. Preferably at least 50 at %, more preferably at least 80 at % of element C is tellurium. Most preferably tellurium is solely used as element C. If a Se percentage in element C is too high, an $ASeC_2$ phase would grow to inhibit growth of an $ASbC_2$ phase.

Any desired method like sputtering and evaporation may be used in forming the mask layer.

The mask layer **32** is sandwiched between the lower and upper dielectric layers **31** and **33**. This sandwich structure not only permits the mask layer which has changed its volume upon irradiation of reading light to quickly return to the original volume, but also prevents the mask layer from any structural change such as segregation and element diffusion during repetitive read-out. Since the mask layer **32** is heated to a somewhat high temperature during read-out, the substrate **2** and protective layer **10** which are formed of less heat resistant resins can be thermally deformed. The lower and upper dielectric layers **31** and **33** are also effective for preventing such thermal deformation by their elastic recovery. The material of which the dielectric layers are formed is not critical. Exemplary dielectric materials include $SiO_2$, mixtures of $SiO_2$ and ZnS, materials containing La, Si, O and N known as LaSiON, materials containing Si, Al, O and N known as SiAlON, SiAlON further containing y, and NdSiON. The dielectric layers may have any desired thickness as long as the above-mentioned effects are fully exerted. In general, the lower dielectric layer is about 10 to about 250 nm thick and the upper dielectric layer is about 10 to about 250 nm thick. The dielectric layers are preferably formed by gas phase deposition methods such as sputtering and evaporation.

The reflecting layer **4** is provided for the purpose of increasing the quantity of reflected light from the medium. Any desirable material may be used to form the reflecting layer. Preferred are high reflectance metals such as Al, Au, Ag, Pt, Cu alone or alloys containing at least one of these elements. The reflecting layer is preferably about 30 to about 150 nm thick. A too thin reflecting layer would fail to provide sufficient reflectance whereas increasing the thickness of the reflecting layer beyond necessity would achieve a slight improvement in reflectance at the expense of cost. The reflecting layer is preferably formed by gas phase deposition methods such as sputtering and evaporation.

The protective layer **10** is provided for the purpose of improving scratch and corrosion resistance. It is preferably formed of organic materials, more preferably radiation-curable compounds and compositions containing the same, which are cured by exposure to radiation, typically electron radiation and ultraviolet radiation. The protective layer is generally about 0.1 to about 100 μm thick. It may be formed by any desirable one of conventional coating methods including spin coating, gravure coating, spray coating, and dipping.

The present invention is also applicable to optical recording media. The optical recording medium is obtained by providing a recording layer above or below the light transmittance control layer of the read only optical information medium thus far described. Where the medium includes a reflecting layer, the recording layer is interposed between the light transmittance control layer and the reflecting layer. Alternatively, the light transmittance control layer is interposed between the recording layer and the reflecting layer. In the former, if desired, a dielectric layer may be formed between the reflecting layer and the recording layer for the purpose of protecting the recording layer and controlling heat release. The substrate of the optical recording medium may be provided with pits for carrying read only information in addition to grooves.

One exemplary structure of the optical recording medium is shown in FIG. **3** as including a substrate **2** having grooves **22**, a light transmittance control layer **3** (including a lower dielectric layer **31**, a mask layer **32**, and an upper dielectric layer **33**), a recording layer **5**, a dielectric layer **6**, a reflecting layer **4**, and a protective layer **10** stacked in the described order from below. It is to be noted that since FIG. **3** is a radial cross section of the medium (typically disc), the direction of relative motion of writing and reading light is perpendicular to the plane of paper of this figure.

When reading light is directed to the recording layer from the light transmittance control layer side, the light beam reaches the recording layer after the beam spot is reduced through the region H or L of the mask layer as in the case of the read only optical information medium mentioned above. This ensures high resolution upon read-out. When reading light enters the medium from the recording layer side, the light beam having passed through the recording layer is selectively transmitted or reflected by the region H or L of the mask layer so that the reflected light with a reduced beam diameter is available from the medium, also achieving high resolution.

Since high resolution is achieved by the above-mentioned mechanism during read-out of the optical recording medium, the benefit of the invention does not depend on the construction of the recording layer. Therefore, the present invention is applicable to magneto-optical recording media having a magneto-optical recording layer of rare earth element-transition metal element alloys, optical recording media having a phase change type recording layer utilizing an amorphous-crystalline phase change of $Sb_2Se_3$, etc., and optical recording media having a write-once recording layer using organic dyes such as cyanine dyes as the recording material. In the case of optical recording media having a phase change type recording layer, the recording layer may be made of the same composition as the above-mentioned mask layer material.

In some media requiring recording light of high power, there is a possibility that the mask layer be melted by irradiation of that recording light and become amorphous after recording. In such a case, the mask layer is preferably initialized (i.e., crystallized) before the start of read-out.

The power of reading light irradiated to the optical information medium of the invention may be determined without undue experimentation. Usually the reading light power $P_R$ is about 1 to about 10 mW although it varies with the construction of the medium and the linear velocity of the beam spot of reading light relative to the medium. Advantageously read-out with a power of less than about 5 mW is possible. The linear velocity of the beam spot of reading light relative to the medium is generally about 1 to about 10 m/s while it may be suitably determined so as to enable read-out through the above-mentioned mechanism.

Although the invention is described in conjunction with a one-side medium having the information carrying or recording means only on one surface of a substrate, the invention is also applicable to a double-sided medium of one type in which a pair of one-side media are joined such that the information carrying or recording means are sealingly located inside or another type in which information carrying or recording means are provided on both sides of a substrate.

## EXAMPLE

Examples of the present invention are given below by way of illustration and not by way of limitation.

### Example 1

An optical recording disc sample was fabricated by injection molding a disc-shaped substrate having a diameter of 130 mm and a thickness of 1.2 mm from polycarbonate while grooves were simultaneously formed in one surface thereof. On the grooved substrate surface, a lower dielectric layer of $ZnS—SiO_2$ having a thickness of 130 nm, a mask layer, an upper dielectric layer of $ZnS—SiO_2$ having a thickness of 180 nm, a phase change recording layer, an uppermost dielectric layer of $ZnS—SiO_2$ having a thickness of 20 nm, a reflecting layer of gold having a thickness of 100 nm, and a protective layer of ultraviolet-cured resin having a thickness of 5 μm were sequentially formed in the described order.

The dielectric layers and reflecting layer were formed by sputtering. Each dielectric layer contained ZnS and $SiO_2$ in a molar ratio of 0.85:0.15. The $ZnS—SiO_2$ had a refractive index of 2.3 at wavelength 780 nm.

The mask layer was 30 nm thick and the recording layer was 20 nm thick. They were formed by sputtering. The mask layer had a composition in atom ratio: $Ag_9Sb_{55}Te_{30}In_5V_1$. The recording layer had the same composition as the mask layer. The target used in sputtering was an antimony target having chips of Ag, In, Te, and V attached thereto.

While the disc sample was rotated at a linear velocity of 2.8 m/s, laser light having a power of 9.0 mW and a wavelength of 780 nm was irradiated to the disc for initializing (or crystallizing) the recording and mask layers. Then signals of 4 MHz were recorded using writing laser light having a power $P_W$ of 15 mW and a wavelength of 780 nm. As a result of recording, the recorded portion was reduced in reflectance.

Next, the portion of the mask layer which had been partially amorphous as a result of irradiation of writing light was initialized (i.e., crystallized). Initialization of the mask layer was to erase recorded signals which had been left in the mask layer after recording. The power of laser light necessary for initialization depended on the linear velocity of the disc sample. Specifically, the power for initialization was 3 mW for a linear velocity of 2.8 m/s, 2.5 to 3 mW for a linear velocity of 1.4 m/s, and 2 mW for a linear velocity of 1 m/s or less.

While rotating the initialized disc sample at a linear velocity of 0.4, 0.6 and 1.4 m/s, reading laser light of 780 nm in wavelength was irradiated to the disc sample. A C/N ratio of read signals was measured while varying the power of reading laser light $P_R$. The results are plotted in FIG. 4. The power of reading light necessary for read-out was about twice the power necessary for initialization. Differential thermal analysis showed that the mask layer had a crystallization temperature of 175° C., a melting point of 525° C., and a crystal-to-crystal transition temperature of about 320° C. This suggested that the mask layer was not melted upon irradiation of reading light, and a crystal-to-crystal transition occurring in the mask layer enabled super-resolution read-out.

The complex refractive index ($n_0-ik_0$) of the mask layer at a wavelength of 780 nm was measured at room temperature and 320° C. To this end, the mask layer was singly formed on a glass substrate and measured for a coefficient of spectral transmission at that wavelength. The results were: $n_0=6.2$ and $k_0=3.2$ at room temperature and $n_0=2.3$ and $k_0=2.5$ at 320° C. Thus a reduction of $n_0$ by a crystal-to-crystal transition of the mask layer was $\Delta n_0=3.9$ and a similar reduction of $k_0$ was $\Delta k_0=0.7$. It is believed from the construction of the disc sample, $\Delta n_0$, $\Delta k_0$, and C/N ratio reported above that the mask layer had increased its volume as a result of a crystal-to-crystal transition.

### Example 2

An optical information medium sample was fabricated as in Example 1 by forming on a substrate in the form of a slide glass of 1.2 mm thick, a lower dielectric layer of 170 nm thick, a mask layer, an upper dielectric layer of 17 nm thick, and a reflecting layer of 100 nm thick in the described order. The dielectric layers, mask layer, and reflecting layer had the same compositions as in Example 1.

The sample was heated to examine the reflectance of the sample at a wavelength of 780 nm relative to the temperature of the mask layer. The reflectance vs. temperature curve is shown in FIG. 5. A sudden increase of reflectance appears at a temperature slightly lower than 200° C. in FIG. 5, which is attributable to crystallization of the mask layer. The reflectance declines as the temperature rises from slightly below 300° C., which is attributable to a crystal-to-crystal transition of the mask layer.

### Example 3

An optical information medium sample was fabricated as in Example 2 by forming on a substrate in the form of a slide glass of 1.2 mm thick, a lower dielectric layer of 170 nm thick, a mask layer, and an upper dielectric layer of 170 nm thick in the described order. The dielectric layers and mask layer had the same compositions as in Example 2.

The sample was heated to examine the transmittance of the sample at a wavelength of 780 nm relative to the temperature of the mask layer. The transmittance vs. temperature curve is shown in FIG. 6. A sudden drop of transmittance appears at a temperature slightly lower than 200° C. in FIG. 6, which is attributable to crystallization of the mask layer. The transmittance increases as the tempera-

ture rises from slightly below 300° C., which is attributable to a crystal-to-crystal transition of the mask layer.

Both the reflectance and transmittance curves of FIGS. **5** and **6** showed moderate changes with a temperature rise probably because the samples were heated at a low rate. The temperature at which such a change started was different between FIGS. **5** and **6** probably because the samples were heated at different rates. The heating rate was 200° C./hour in FIG. **5** and 400° C./hour in FIG. **6**.

Equivalent results were observed when the mask layer was formed of $Ag_{52.5}Zn_{47.5}$ having a crystal-to-crystal transition temperature of 280° C. and $Te_{50.6}Ge_{49.4}$ having a crystal-to-crystal transition temperature of 360° C.

The effectiveness of the present invention is evident from the results of Examples.

Japanese Patent Application No. 164577/1994 is incorporated herein by reference.

While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it will be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

We claim:

**1**. An optical information medium comprising a substrate having pits formed on one surface for carrying information and a light transmittance control layer on the substrate surface including a lower dielectric layer, a mask layer and an upper dielectric layer, and further comprising:

- a reflecting layer of 3 to 150 nm thick formed at least one of above and below said light transmittance control layer,
- the mask layer having an original state before irradiation by reading light and is 3 to 100 nm thick,
- the mask layer undergoing a crystal-to-crystal transition upon irradiation by reading light to introduce a change in the reflectance of the reading light, the crystal-to-crystal transition taking place at a temperature of 200 to 450 degrees C, and
- the mask layer returning to the original state after irradiation by reading light.

**2**. An optical information medium comprising a substrate, a light transmittance control layer on a surface of the substrate and including a lower dielectric layer, a mask layer and an upper dielectric layer, and a recording layer formed at least one of above and below said light transmittance control layer, and further comprising:

- a reflecting layer of 3 to 150 nm thick, at least one of: (1) said recording layer being interposed between said light transmittance control layer and said reflecting layer and (2) said light transmittance control layer being interposed between said recording layer and said reflecting layer,
- the mask layer having an original state before irradiation by reading light and is 3 to 100 nm thick,
- the mask layer undergoing a crystal-to-crystal transition upon irradiation by reading light to introduce a change in the reflectance of the reading light, the crystal-to-crystal transition taking place at a temperature of 200 to 450 degrees C, and
- the mask layer returning to the original state after irradiation by reading light.

**3**. The optical information medium of claim **2** and which is an optical recording medium wherein said recording layer is at least one of a phase change type and a magneto-optical type.

**4**. The optical information medium of claim **2** which is an optical recording medium wherein said recording layer is at least one of the phase change type and magneto-optical type.

**5**. The optical information medium of claim **2**, wherein said mask layer contains silver and zinc as main components and the Zn/(Zn+Ag) ratio is 40 to 60 at %.

**6**. The optical information medium of claim **2**, wherein said mask layer contains tellurium and germanium as main components and the Ge/(Te+Ge) ratio is 20 to 60 at %.

**7**. The optical information medium of claim **2** wherein said mask layer contains elements A, B and C, wherein A is silver, gold or a mixture thereof, B is antimony, bismuth or a mixture thereof, and C is tellurium, selenium or a mixture thereof.

**8**. The optical information medium of claim **2**, wherein said mask layer has an original volume before irradiation by reading light,

- the mask layer changing its volume as a result of the crystal-to-crystal transition of the mask layer upon irradiation of reading light, and
- the mask layer returning to the original volume after irradiation by reading light.

**9**. The optical information medium of claim **1**, wherein said mask layer contains silver and zinc as main components and wherein the Zn/(Zn+Ag) ratio is 40 to 60 at %.

**10**. The optical information medium of claim **1**, wherein said mask layer contains tellurium and germanium as main components and wherein the Ge/(Te+Ge) ratio is 20 to 60 at %.

**11**. The optical information medium of claim **1** wherein said mask layer contains elements A, B, and C wherein A is silver, gold or a mixture thereof, B is antimony, bismuth or a mixture thereof, and C is tellurium, selenium or a mixture thereof.

**12**. The optical information medium of claim **11** wherein said mask layer further contains indium.

**13**. The optical information medium of claim **12** wherein said mask layer further contains at least one element M selected from the group consisting of Ti, Zr, Hf, V, Nb, Ta, Mn, W, and Mo.

**14**. The optical information medium of claim **1**, wherein the mask layer has an original volume before irradiation by reading light,

- the mask layer changing its volume as a result of the crystal-to-crystal transition of the mask layer upon irradiation by reading light, and
- the mask layer returning to the original volume after irradiation by reading light.

* * * * *

US005516568A

# United States Patent [19]

Jung

[11] Patent Number: 5,516,568

[45] Date of Patent: May 14, 1996

[54] **OPTICAL RECORDING MEDIUM**

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[21] Appl. No.: **487,350**

[22] Filed: **Jun. 7, 1995**

**Related U.S. Application Data**

[62] Division of Ser. No. 175,839, Dec. 30, 1993.

[51] **Int. Cl.**$^{6}$ .......... **B32B 3/00**

[52] **U.S. Cl.** .......... **428/64.1**; 428/64.2; 428/64.4; 428/64.8; 428/913; 430/270.1; 430/495.1; 430/945; 369/272; 369/275.1; 369/275.2; 369/283; 369/288

[58] **Field of Search** .......... 428/64.1, 64.1, 428/64.4, 64.8, 913; 430/270, 495, 945; 369/272, 275.1, 275.2, 283, 288

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[57] **ABSTRACT**

There is disclosed an organic optical recording medium with high data storage density, high data rates and long data archival capabilities, useful as a medium for recording a variety of information or pictures.

In a preferred embodiment, the optical recording medium according to the present invention comprises a substrate, a reflective layer, a charge-generating layer containing at least one charge-generating material, a charge-transferring layer containing at least one charge-transferring material, a recording layer containing at least one electric field-discoloring element, a plurality of spacers, an air layer and a protective layer.

A laser beam is absorbed to the charge-generating material contained in the charge-generating layer, to generate charges, which are subsequently transferred to the surface of the recording layer by the charge-transferring layer.

With the influence of the charge generated, the illuminated area having the charges puts on a color different from that in the other areas. In readout of the recorded information, a laser beam of lesser intensity is scanned across the recorded medium. The erasure of the recorded data is carried out by discharging the charges generated on the surface of the recording layer. As a result, the erasure in the optical recording medium is performed much simpler.

**4 Claims, 1 Drawing Sheet**

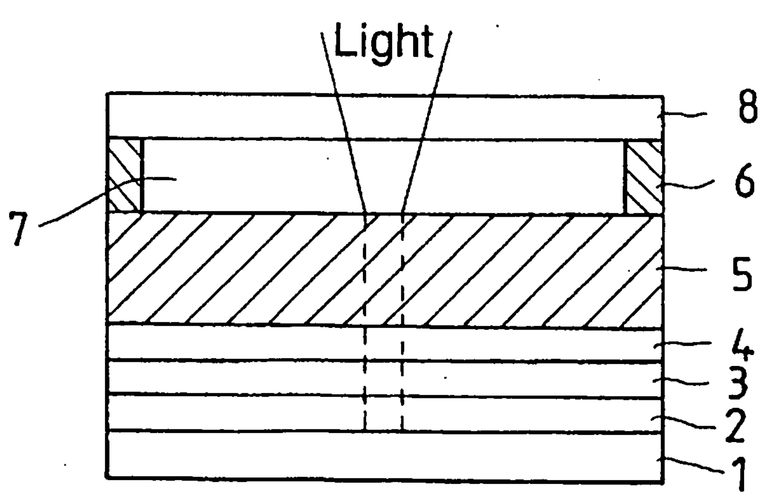


FIG 1

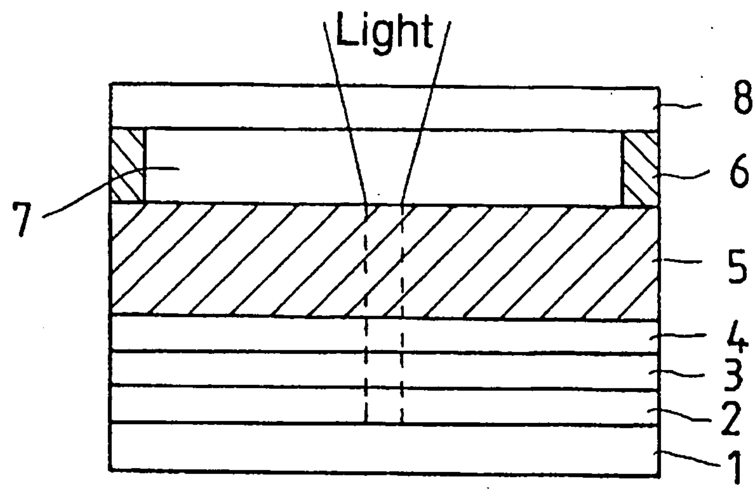



FIG 2

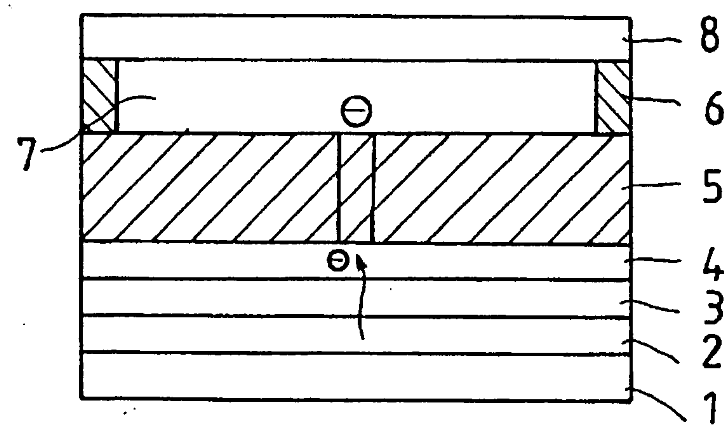
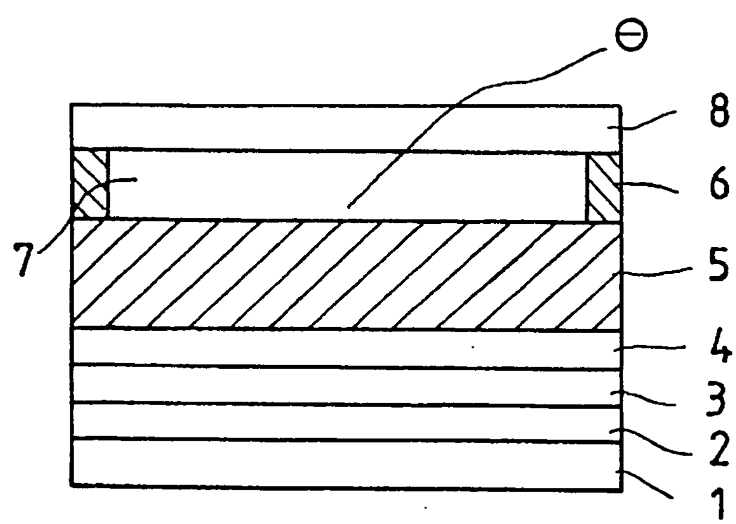



FIG 3



# OPTICAL RECORDING MEDIUM

This is a division of application Ser. No. 08/175,839, filed Dec. 30, 1993, pending.

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates, in general, to an organic, optical data storage medium which is recordable, readable and erasable by using laser beam and, more particularly, to an organic, optical recording medium with high data storage density, high data rates and long data archival capabilities, useful as a medium for recording a variety of information or pictures.

### 2. Description of the Prior Art

The variety and amount of information has increased at an explosive rate in today's information-intensive society. Such an information increase requires recording media to be higher in data storage capacity or density, data rate, and to be faster in operation.

Currently, the practical or commercial techniques for recording data are based substantially on magnetic storage technology. In general, the data are stored on magnetic media, such as video tapes, audio tapes, floppy discs and the like, on which information is recorded depending on the direction of magnetization of magnetic substances in the magnetic medium.

While the magnetic storage technology is commercially successful and advantageous, a recording technique known generically as optical recordings has been and continues to be considered a very promising alternative for storage data, as a recording media with higher capacity is demanded according to the enormous amount of information resulting from the society development.

A magneto-optic recording medium comprises a recording film magnetizable in the direction perpendicular to the plane of the film itself, in contrast to the conventional magnetic medium. In addition, the coercive force of a magneto-optical medium, which is a measurement of strength maintaining the previous direction of magnetization, is about 5 to 10 times as high as that of a magnetic medium. Accordingly, using a magneto-optic recording medium, it is very difficult to change the previous direction of magnetization with an external magnetic field.

The recording of information on a magneto-optic recording film is effected by first focusing a modulated laser beam at a point approximately 1 μm in diameter on the surface of the film. The laser beam power should be sufficient to heat the film locally, for example, to the Curie point temperature of the film. In this state, the direction of magnetization can be changed with an external magnetic field, so as to record information on the film according to the direction.

When the information is recorded by this method, the storage unit of information comes to be reduced to approximately 1 μm or less in size. Accordingly, the recording density of magneto-optical medium is 10 to 1,000 times greater than that of conventional magnetic recording medium. In addition, the magneto-optical medium employs a non-contact reproducing method, so that magneto-optical recording potentially has significant advantages over magnetic recording, including easier data preservation and longer data archival capability.

However, there have historically been many disadvantages in producing the magneto-optic recording media used in such method. For example, heavy metals are commonly



used as magnetic substances and a vacuum deposition or sputtering apparatus is required.

Many attempts have been made to solve such disadvantages. One of the attempts is to develop an organic optical recording material. The organic optical recording material may be grouped into (1) a write-once/read-many (hereinafter, referred as "WORM") type, and (2) a rewritable (hereinafter, "RW") type on the basis of the erasability of the material.

On the WORM type material, only readout of information is possible after recording data once, whereas, on the RW type material, erasure of the data is also possible after recording.

WORM type medium is manufactured, as disclosed in Japanese Patent Laid-Open Publication Nos. Sho. 57-46362, 58-197088, 59-5096 and 63-179792, by coating laser-absorbent dye admixtured with polymer on a reflective layer to form a recording layer and overcoating a protective layer on the recording layer. In this optical recording system, to write a data bit, a laser beam is focused on a very small spot of the recording layer, for example, approximately 1 μm or less in diameter, to generate sufficient heat in the laser-absorbent dye, which heat decomposes the polymer to form a pit. The reproduction of the recorded information is effected by using the difference of the reflectivity according to the presence of the pit. Since, in WORM type material, the recorded portion is in a polymer-decomposed state, it is impossible to rerecord data on the polymer-decomposed portion after erasing the information.

A RW type material has been vigorously researched and the direction of the research proceeds to a heat mode using a light as heat or to a photon mode using a photon of light.

In the heat mode, the recording or reproducing of information is effected by optical change generated when a recording laser beam is irradiated to a localized area of the recording layer to bring out melting, vaporization, thermal deformation, thermal transfer and the like.

As an optical recording medium employed in such heat mode, there have been energetically studied two optical mediums, wherein one medium employs TbFe, CdFe, TbFeCo and the like, taking advantage of the Paraday effect and the Kerr effect. The other heat mode optical recording medium employs inorganic metals represented as Te, such as TeOX, Te—Ge, Te—Ge—Sb, and Te—Ge—Sb—Ti. However, since this heat mode optical medium employs a material harmful to human body and it is produced, employing a sputtering method, the stability of the medium is low and it is difficult to carry out the production process. What is worse, the heat mode optical medium shows low recording sensibility and is problematic in the stability of recorded state and the write-over capability on high speed erasure.

Therefore, there is demanded a nontoxic, low-priced medium capable of erasing data in a high speed and of showing high recording sensibility and stability.

To develop a material for satisfying these properties, a variety of methods employing a nontoxic, low-cost, organic polymeric material have been suggested.

For example, a method utilizing a thermoplastic resin and a far infrared ray-absorbent dye has been disclosed in Japanese Patent No. 5848245 and a method using a polymer blend has been proposed in U.S. Pat. No. 4,722,595. However, these methods are problematic in recording sensitivity and recording/erasure repetition.

A variety of methods utilizing the phase transfer of liquid crystal have been proposed in Japanese Patent Laid-Open

Publication Nos. Sho. 59-10930, 60-114823 and 60-166481, and U.S. Pat. No. 4,904,066. However, since an electrode is employed in these patents, the structure of the medium is complicated and there are disadvantages in recording sensitivity, responsibility and reliability.

As polymeric liquid crystal materials used in optical recording, main chain type liquid crystal polymers have been reported in Japanese Patent Nos. 6128004 and 62175939 and side chain type liquid crystal polymers have been described in German Patent No. 3500838. However, they can not be put into practical use since their recording sensitivity, contrast and repetitive erasability are unsatisfactory and the speed of response is slow.

To improve the responsibility of liquid crystal, a photoisomeric method has been advanced in Japanese Patent No. 6398852, by which a photochromic molecule, such as azobenzene, is bonded to a side chain of a polypeptide having a photochromic liquid crystal layer, using the relation between photoreaction and liquid crystal. However, this method also shows some problems in contrast, repetitive erasability and data archival capability and thus, is not industrially available.

In the meantime, the optical recording method according to the photon mode has attracted attention by virtue of its high sensibility and high speed erasure. As an optical recording material, there have been photochromic materials using spiropyran compounds in Japanese Patent Publication No. Sho. 61-17037, fulgid or indigo in Japanese Patent Publication No. Sho. 61-128244.

However, while these materials have superior such properties as high sensitivity and high speed erasure, they are inferior in stability and repetitive erasability in a color developing state due to their poor light resistance. In addition, since an ultra violet ray and a visible ray are, in general, used as a recording light and an erasing light, respectively, in photochromic compounds, it is difficult to stably store data and a reverse reaction is apt to occur during a photochromic reaction.

Owing to the aforementioned problems, the optical recording medium has not been rapidly developed in spite of its superior properties, such as high data storage density and high speed.

## BRIEF SUMMARY OF THE INVENTION

For solving the problems encountered in the prior art, the present inventors have recognized that there exist needs for the improvement in the aspects of stability, sensitivity and complexity of erasing system and for a novel, organic optical recording medium having these advantages, in order to provide a new method of optical recording.

Accordingly, it is an object of the present invention to provide an optical medium, superior in recording sensitivity.

It is another object of the present invention to provide an optical medium, improved in long archival capability.

It is further an object of the present invention to provide an optical medium, capable of erasing data in a high speed.

It is still another object of the present invention to provide an optical medium with higher data storage density.

In accordance with the present invention, the above object can be accomplished by providing an optical recording medium, comprising: a reflective layer formed over a substrate layer, reflecting an incident laser beam with a predetermined wavelength; a charge-generating layer coated on the upper surface of the reflective layer, containing at least one charge-generating material, the incident laser beam generating charges on the charge-generating layer; a charge-transferring layer coated on the upper surface of the charge-generating layer, containing at least one charge-transferring material transferring the charges from the charge-generating layer into an upper layer thereof; a recording layer coated over the charge-transferring layer, containing at least one electric field discoloring element, the transferred charges discoloring the electric field discoloring element in the area illuminated by the laser beam, so as to record information; a protective layer formed over the recording layer; and in case of need a plurality of spacers formed on the both upper sides of the recording layer, forming an air layer therebetween.

## BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and aspects of the invention will become apparent from the following description of embodiments with reference to the accompanying drawings in which:

FIG. 1 is a schematic, cross-sectional view showing the structure of an optical recording medium according to an embodiment of the present invention;

FIG. 2 is a schematic, cross-sectional view illustrating the recording procedure of an optical recording medium, according to an embodiment of the present invention; and

FIG. 3 is a schematic, cross-sectional view illustrating the erasing procedure of an optical recording medium, according to an embodiment of the present invention.

## DETAILED DISCLOSURE OF THE INVENTION

Hereinafter, the preferred embodiment of the present invention will be, in detail, described with reference to the accompanying drawings, wherein like reference numerals designate like parts, respectively.

FIG. 1 illustrates in simplified form the essential features of an embodiment of the present invention employing longitudinal optical recording. As shown in this drawing, the optical recording medium according to the present invention comprises a substrate **1**, a reflective layer **2**, a charge-generating layer **3** containing at least one charge-generating material, a charge-transferring layer **4** containing at least one charge-transferring material, a recording layer **5** containing at least one electric field-discoloring element, a plurality of spacers **6**, an air layer **7** and a protective layer **8**, in some cases spacers **6** and air layer **7** can be omitted. In this drawing, there is shown a laser beam which is focused on an area to be recorded.

Referring now to FIG. **2**, there is illustrated a recording procedure in the optical recording medium of FIG. **1**, according to the present invention.

As illustrated in this drawings, the irradiated laser beam having a wavelength range necessary to record data is absorbed to the charge-generating material in the charge-generating layer, to generate, on the surface of the charge-generating layer, a charge, which is subsequently transferred to the surface of the recording layer by the charge-transferring layer. Therefore, an electric field effect is generated on the area illuminated with the laser beam.

With the influence of the charge generated, the illuminated area having the charge puts on a color different from that in the other, non-illuminated areas. The recording of information on such a medium is effected through the above procedure.

In readout of the recorded information, a laser beam of intensity lesser than that of the laser beam intensity used in recording, that is, a laser beam having an energy incapable of generating the charge is scanned across the recorded medium, a technique being employed to reproduce information relaying upon the difference of the light transmitted through or reflected from the optical recording medium.

Turning now to FIG. **3**, there is illustrated an erasure procedure in the optical recording medium of FIG. **1**, according to the present invention.

As illustrated in this drawing, the erasure of the recorded data is carried out by discharging the charge generated on the surface of the recording layer **5**. As a result, the erasure in the inventive optical recording medium is performed much simpler than in the conventional organic optical erasing system.

The reflective layer **2** is deposited with a metallic ingredient in a thickness ranging from approximately 50 to approximately 1,000 Å and preferably selected from the group consisting of gold and aluminum.

As materials for the charge-generating layer **3** and the charge-transferring layer **4**, either inorganic materials or organic materials can be utilized.

The inorganic materials utilized for the charge-generating layer **3** and the charge-transferring layer can include seleniums, cadmium sulfides, zinc oxides and amorphous silicons. The use of inorganic material allows the charge-generating layer and the charge-transferring layer to be one layer, since an inorganic material generally has the properties of charge generation and charge transfer, at the same time.

On the other hand, when the charge-generating layer **3** employs an organic material as a charge-generating material, it is formed by dispersing at least one charge-generating material in a resin and coating the resulting solution on the reflective layer **2**.

The resin used for the charge-generating layer **3** must be capable of transmitting at least 80% of the incident laser beam with a recordable wavelength band, and can include polycarbonate, poly(methyl methacrylate), polystyrene and amorphous polyolefin. Polycarbonate resin is generally used for the charge-generating layer **3**.

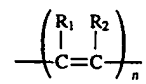
The charge-generating materials are used, as being dispersed in the resin. Preferred charge-generating material includes at least one compound selected from the group consisting of polyazos, phenylene tetracarboxy diimides, polycyclic quinones, phthalocyanines, squaryliums and phiapyryliums.

The charge-transferring layer **4** coated on the charge-generating layer **3** comprises a resin used in the charge-generating layer **3** and at least one charge-transferring material. The charge-transferring materials are used, as being dispersed in the resin. Preferred charge-transferring material includes at least one selected from the group consisting of pyrazolines, stilbenes, hydrazones, triphenyl methanes, heterocyclics and conjugated arylamides.

The charge-generating layer **3** is preferably formed in a thickness ranging from approximately 0.1 μm to approximately 0.3 μm, whereas the charge-transferring layer **4** is preferably formed in a thickness ranging from approximately 3 to approximately 30 μm.

The materials for the charge-generating layer **3** and the charge-transferring layer **4** would be readily apparent to a person of ordinary skill in the art having the benefit of this disclosure and are to be suitably selected, according to the recordable wavelength band of laser.

The electric field discoloring element used in the present invention is to effect high reflectivity in the recording layer **5** and is a material capable of transmitting at least 70% of the incident laser beam with a recordable wavelength band. As an electric field discoloring element, there may be employed all conductive polymers which can be discolored by an electric field, preferably compounds represented as the following formulas I through VII and most preferably polypyrrole, represented as the following formula III.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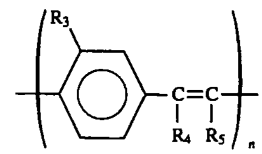
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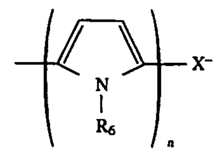
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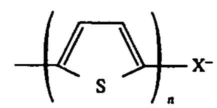
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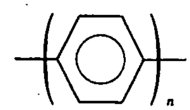
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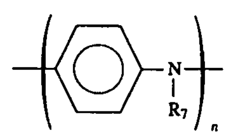
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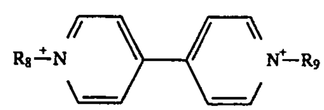

(VII)

wherein n is an integer not less than 4; $R_1$ to $R_9$ is hydrogen, an alkyl group, an alkoxy group or a phenyl group; and $X^-$ is $ClO_4^-$, $BF_4^-$ or $AsF_5^-$.

In case of using the compounds represented as the above formulas, the compounds are electro-polymerized and coated on the charge-transferring layer **4** in a thickness not more than approximately 20 μm. The amount of the compound is preferably on the order of approximately 0.2% to approximately 20% by weight, based on the weight of the solvent used. For example, if too little of the compound is used, the discoloring degree caused by an electric field is so low that there may be generated a problem in its recording property. On the other hand, if too much of the compound is used, a light absorption rate becomes too large to obtain a reflectivity value necessary for to the recording of information.

The discoloring of the recording layer **5** is easily recognized, since the recording layer **5** employing the above electric field discoloring element, for example, polypyrrole, puts on a blue color in an oxidized state, whereas the polypyrrole discoloring element in the recording layer is a yellowish green color in a reduced state.

A pair of spacers **6** can be formed on both upper side regions of the recording layer **5** comprising the electric field discoloring element, maintaining an air layer **7** therebe-

tween, in accordance with the present invention. Preferred materials for the spacers **6** include glass bead.

A protective layer **8** can be formed over the recording layer **5**. If present, the air layer **7** is formed between the recording layer **5** and the protective layer **8**, according to the present invention. The protective layer **8** can be made of the same material as the substrate **1** and preferably of polycarbonate.

The present invention can further employ a photo mask over the recording layer **5** comprising the electric field discoloring element, effecting a more stable recording state. When used, the photo mask has to be divided into a size as large as the focus of the incident laser beam and preferably not more than 3 μm.

The recording and erasing procedure of the inventive optical recording medium is as described above and of which a brief summary is given in FIGS. **2** and **3**.

The organic, optical recording medium provided in accordance with the present invention is superior in recording sensitivity and data stability.

Now, the preferred embodiment of the present invention will be further described with reference to the following specific examples.

## EXAMPLE 1

Gold (Au) was deposited on a polycarbonate substrate in a thickness of 800 Å. Polycarbonate resin and PROGEN, a phthalocyanine compound used as a charge-generating material and commercially available from ICI company, were dissolved in a solvent to give a solution wherein the weight ratio of polycarbonate to the charge-generating material was 50:50. Then, the solution was spin-coated on the deposited substrate in a thickness of 0.2 μm and stored at 80° C. for 10 hours to remove the solvent from the substrate.

On this charge-generating layer, there was coated a solution wherein polycarbonate and a charge-transferring material were dissolved in a solvent in weight ratio 50:50 of polycarbonate to the charge-transferring material. The solvent was dried out under the same conditions as the above. As the charge-transferring material, PROPRANT, a hydrazone compound commercially available from ICI company, was used.

On the charge-transferring layer formed, a solution of electropolymerized polypyrrole, an electric field discoloring material, and a solvent wherein polypyrrole amounted to 5% by weight of the solvent, were spin-coated in a thickness of 5 μm. The resulting structure was heated to 80° C. in an oven for 5 hours, to remove the solvent sufficiently. The molecular structure of polypyrrole used as a material for a recording layer was given as designated formula III-1 in the following Table 1.

On both upper side regions of the recording layer, there were formed spacers of glass bead, followed by the formation of polycarbonate plate thereon, so as to prepare an optical recording medium.

Reflectivity of the prepared medium was measured with respect to a light source with a wavelength of 780 nm, to obtain a reflectivity value of 45%. As apparent from this value, it has high reflectivity as a recording medium.

Measurement was carried out with a modulated laser beam ($\lambda$=780 nm) with 10 mW, under the conditions of 0.1 μm sec., 600 rpm and 300 KHz, recording a result. It was ascertained that the recording area appeared yellowish green under an electrostatic state. Thereafter, a laser beam ($\lambda$=780 nm) with 1.0 mW was irradiated in the same condition as the above, recording a result. From the results, C/N ratio (hereinafter, referred as "CNR") was measured to obtain a CNR value of 57 dB. This CNR value is to confirm that the organic optical recording material is superior in recording property to other erasable, organic optical recording materials.

The organic optical recording medium was left at a temperature of 40° C. and a relative humidity of 80% for 10 days and was then subjected to the measurement, to obtain a CNR value of 56 dB. The organic optical recording medium also was left at temperature of −10° C. for 10 days, obtaining the same CNR value, 56 dB. These results also verify that the medium according to the present invention is a stable, organic optical recording material in any condition.

After the recording and reproducing was iteratively performed 300 times, the property of the recording and erasure were measured, to obtain a superior result of a CNR value of 56 dB.

The results are, in detail, given as shown in the following Table 1.

## EXAMPLE 2

An optical recording medium was prepared in a manner similar to that in Example 1, except that, as an electric field discoloring element, a compound of general formula VI (detailed molecular formula VI-1 given in Table 1) was used.

Testing for the recording, erasure and reliability was iteratively performed and the properties were measured, under the same conditions as Example 1.

As a result, the reflectivity was similar to that in Example 1 and CNR from the test of recording/erasure/reliability was a bit less than in Example 1 but superior to other conventional recording materials. The results of the testing are, in detail, given as shown in the following Table 1.

## EXAMPLE 3

An optical recording medium was prepared in a manner similar to that in Example 1, except that, as an electric field discoloring element, a compound of general formula IV (detailed molecular formula IV-1 given in Table 1) was used.

Testing for the recording, erasure and reliability was iteratively performed and the properties were measured, under the same conditions as Example 1.

As a result, the properties were as superior as those in Example 2. The results are, in detail, given as shown in the following Table 1.

## EXAMPLE 4

An optical recording medium was prepared in a manner similar to that in Example 1, except that, as an electric field discoloring element, a compound of general formula II (detailed molecular formula II-1 given in Table 1) was used.

Testing for the recording, erasure and reliability was iteratively performed and the properties were measured, under the same conditions as Example 1.

As a result, the properties were as superior as those in Example 2. The results are, in detail, given as shown in the following Table 1.

## EXAMPLE 5

An optical recording medium was prepared in a manner similar to that in Example 1, except that, as an electric field discoloring element, a compound of general formula VII

(detailed molecular formula VII-1 given in Table 1) was used.

Testing for the recording, erasure and reliability was iteratively performed and the properties were measured, under the same conditions as Example 1.

The results are, in detail, given as shown in the following Table 1.

## EXAMPLE 6

An optical recording medium was prepared in a manner similar to that in Example 1, except that, as an electric field discoloring element, a compound of general formula V (detailed molecular formula V-1 given in Table 1) was used.

Testing for the recording, erasure and reliability was iteratively performed and the properties were measured, under the same conditions as Example 1.

The results are, in detail, given as shown in the following Table 1.

## EXAMPLE 7

An optical recording medium was prepared in a manner similar to that in Example 1, except that, as an electric field discoloring element, a compound of general formula I (detailed molecular formula I-1 given in Table 1) was used.

Testing for the recording, erasure and reliability was iteratively performed and the properties were measured, under the same conditions as Example 1.

The results are, in detail, given as shown in the following Table 1.

## EXAMPLE 8

An optical recording medium was prepared in a manner similar to that in Example 1, except that a selenium layer is formed in a thickness of 0.5 μm as a charge-generating and charge-transferring section in lieu of separate charge-generating and charge-transferring layers.

Testing for the recording, erasure and reliability was iteratively performed and the properties were measured, under the same conditions as Example 1.

The results are, in detail, given as shown in the following Table 1.

## EXAMPLE 9

An optical recording medium was prepared in a manner similar to that in Example 1, except that a photo mask was placed on the recording layer comprising an electric field discoloring element.

Testing for the recording, erasure, and reliability was iteratively performed and the properties were measured, under the same conditions as Example 1. As a result, there was obtained a recording resolution of about 1.2 μm, which was superior to the approximately 2 μm recording resolution value from the other Examples 1 through 8. The other properties were similar to those in the other Examples, as given in Table 1.

Consequently, the use of photo mask allows the optical recording medium to be improved.

## COMPARATIVE EXAMPLE 1

An optical recording medium was prepared in a manner similar to that in Example 1, except that an electric field discoloring element amounted to 25% by weight of the solvent.

Testing for the recording, erasure and reliability was iteratively performed and the properties were measured under the same conditions as Example 1.

From the result of the test, it was found that since the transmission of the light was reduced at the high concentration of the electric field discoloring element, which resulted, in turn, in lowering the reflectivity, this medium was inferior in its general properties as a recording material as compared to the recording material of the other Examples. Accordingly, this optical recording medium was proved to be problematic, as a recording material.

The results are, in detail, given as shown in the following Table 1.

## COMPARATIVE EXAMPLE 2

An optical recording medium was prepared in a manner similar to that in Example 1, except that, as a resin, polypropylene was used in lieu of polycarbonate.

Testing for the recording, erasure and reliability was iteratively performed and the properties were measured, under the same conditions as Example 1. However, the reflectivity was very low, so that the recording and erasure was difficult.

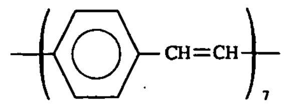
TABLE 1

| | | | Conc. of | CNR (dB) After | | | |
|---|---|---|---|---|---|---|---|
| Exm. No. | Reflectivity (unrecorded area) | E.F.E.* (record layer) | Rec. layer (wt %) | Initial Record | 300 times | Hot test# | Cold test## |
| 1 | 45% | III-1 | 5 | 57 | 56 | 56 | 56 |
| 2 | 42% | VI-1 | 5 | 51 | 49 | 48 | 49 |
| 3 | 42% | IV-1 | 5 | 50 | 49 | 48 | 48 |
| 4 | 43% | II-1 | 5 | 51 | 50 | 46 | 47 |
| 5 | 46% | VII-1 | 5 | 58 | 56 | 56 | 56 |
| 6 | 45% | V-1 | 5 | 51 | 50 | 47 | 47 |
| 7 | 45% | I-1 | 5 | 51 | 50 | 47 | 47 |
| 8 | 44% | III-1 | 5 | 50 | 48 | 49 | 49 |
| 9 | 42% | III-1 | 5 | 50 | 48 | 49 | 49 |
| C-1 | 20% | III-1 | 25 | 20 | 10 | 9 | 8 |
| C-2 | 11% | III-1 | 5 | — | — | — | — |

Detailed molecular formulas:

TABLE 1-continued

$-(CH=CH)_6-$ (I-1)



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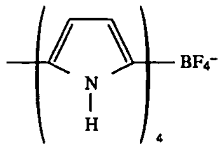
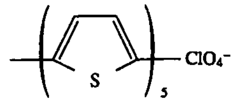
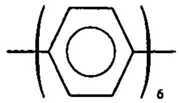


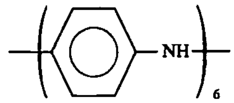
(III-1)



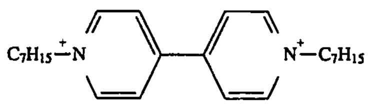
(IV-1)



(V-1)



(VI-1)



(VII-1)

#: test for sample left at 40° C., 80% RH for 10 days
##: test for sample left at −10° C. for 10 days
*: electric field discoloring element

As apparent from the Examples and Comparative Examples, the optical recording medium according to the present invention, has superior properties, e.g., high data storage density, high data rates and long data archival capability.

Although the preferred embodiments of the invention have been disclosed for illustrative purpose, those skilled in the art will appreciate that various modifications and additions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

I claim:

1. A method for recording, reading and erasing information on an optical recording medium having a substrata layer, a reflective layer, a charge-generating and transferring section comprised of charge-generating material and charge-transferring material, respectively, and a recording layer, said method comprising the steps of:

recording the information by illuminating the charge-generating material with a laser beam having a wavelength and intensity capable of generating a charge, and transferring the charge to the recording layer having a discoloring element whereby said discoloring elements puts on a color in a charged state different than in an uncharged state;

reading the recorded information by illuminating with a laser beam on the recording medium, wherein, said laser beam for reading said recorded information has a lesser intensity than the laser beam used to record the information; and

erasing the recorded information by discharging the charge generated and transferring to the recording layer.

2. A method for recording information on the optical recording medium of claim 1, wherein said method comprises illuminating the charge-generating material with a laser beam having a wavelength and intensity capable of generating a charge, wherein said charge is transferred to the recording layer having a discoloring element whereby said discoloring element puts on a color in a charged state different than in an uncharged state.

3. A method for reading information recorded on the optical recording medium of claim 1 wherein said reading method comprises illuminating with a laser beam said optical recording medium having recorded information, wherein said laser beam for reading said recorded information has a lesser intensity than the laser beam used to record the information.

4. A method for erasing recorded information from the optical recording medium of claim 1 wherein said method comprises discharging the charge generated and transferred to the recording layer.

* * * * *

Document 1.

# 50-mm CAD-MSR Disk System with Blue Laser

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## ABSTRACT

A mobile magneto-optical disk system with 2 Gbytes user-capacity is proposed. The disk consists of a center aperture detection type of magnetically induced super-resolution medium, a 0.5 mm thickness substrate with 50 mm in diameter, and a newly developed ultraviolet curing resin film to keep the disk tilt small even if its surrounding environmental condition changes. The optics contains a blue laser diode of a 406 nm wavelength and an objective lens with a numerical aperture of 0.6. A laser pulsed magnetic field modulation method is employed and it realizes land and groove recording with an effective track pitch of 0.40 μm. Practicable system margin values are confirmed at 0.146 μm bit density (11 Gbits/in$^2$ areal density.)

Keywords: Magneto-optical disk, center aperture detection, magnetically induced super resolution, land and groove recording, laser pulsed magnetic field modulation

## 1. INTRODUCTION

A center aperture detection type of magnetically induced super-resolution (CAD-MSR) medium for red laser optics had been studied[1-3], and it had already been in commercial use as like iD-photo[4]. In order to obtain more huge capacity, CAD-MSR media had been modified to be suitable for blue laser recording[5,6]. The combination of CAD-MSR media and blue laser optics enabled us to realize an acceptable capacity disk system for mobile audio-visual applications.
This paper describes a 2 Gbytes user-capacity disk system with a 50 mm diameter CAD-MSR disk. Firstly, key technologies in this study are introduced. Secondly, the 0.5 mm thickness disk properties are reported. Realizing the 0.5 mm thickness disk was one of key issues in this study. We utilized an amorphous polyolefin polymer as the substrate material and developed a novel ultraviolet curing (UV) resin material for a protective film formed on the CAD-MSR medium. The completed disk, consisted of the injection molding substrate with a 0.5 mm thickness, the CAD-MSR medium, and the newly developed UV resin protective film, showed very small disk tilt and it was kept even in severe environmental tests. Finally, experimental results for readout and recording characteristics are reported. The obtained margin values proofed that the proposed system was available for practical use.

## 2. KEY TECHNOLOGIES

Key technologies in this study are illustrated in Fig. 1. It is our proposal to realize a mobile consumer use product with acceptable wide system margins. A blue laser diode made by Nichia Corporation was used in this study. The wavelength was 406 nm. A moderate 0.6 numerical aperture (NA) objective lens was utilized as like conventional far field optics. The substrate dimensions were 50 mm in diameter and 0.5 mm in thick. The latter induced relatively larger tilt tolerances in comparison with the thicker substrate. The substrate was fabricated by an injection molding process. The effective track pitch was 0.4 μm and its depth was 35 nm. The groove depth was set to obtain good margin balance between lands and grooves. Such dimensions of grooves were duplicated through a reactive ion etching (RIE) glass mastering process. It brought a good bit error rate (BER) of magneto optical (MO) signal. An improved CAD-MSR medium for blue laser recording was supplied to this study[7]. It was a magneto-static type of CAD-MSR medium and it had higher recording


Optical Data Storage 2001, Terril Hurst, Seiji Kobayashi, Editors, Proceedings of SPIE Vol. 4342 (2002) © 2002 SPIE · 0277-786X/02/$15.00

power sensitivity and higher recording magnetic field sensitivity suitable for mobile drives with lower electric consumption. A newly developed UV resin protective film was employed to reduce the transient disk tilt even if the surrounding environment c hanges. It is one of the most important technologies because it enabled the 0.5 mm thickness disk to be in practical use, and our proposal system was realized. A laser pulsed magnetic field modulation method was adopted in this system and it enabled for us to achieve land and groove recording with a narrow 0.4 μm track pitch. By combining those components, available system margins were obtained at an areal density of 11 Gbits/in$^2$.

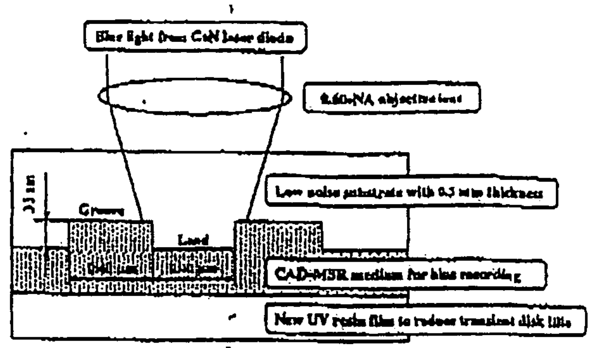


Figure 1: Key technologies in this study.

## 3. FABRICATION OF 0.5 MM THICKNESS SUBSTRATE

### 3.1 RIE glass mastering

An RIE glass mastering technique was adopted in this study[8]. Figure 2 shows the farmer part of disk fabrication processes. A positive type photo resist was spin-coated on a quartz glass substrate. The typical thickness of resist was 70 nm to obtain the groove depth of 35-40 nm. Laser cutting (exposure) process was carried out and the exposed resist was removed by developing. Generally this remaining resist pattern is utilized as a photo resist master to fabricate a stamper for the injection molding. In this study the quartz glass was reactive-ion-etched with CF4 gas, and the etched grooves were formed directly on the glass surface. In detail, the photo resist pattern was also etched with a similar etching rate, and the remaining photo resist was removed after etching.

Figure 3 shows an atomic force microscope (AFM) image of the RIE glass master. The etching power was 400 watts. The centerline average roughness of etched groove surface was less than 0.2 nm. It was a quite small value as well as the quartz glass surface or the land surface. The land portion was not etched because it was covered by the photo resist. Additionally in the RIE process, the land width of the RIE glass mater hardly depend on that of the covered photo resist pattern. It only depends on the dimensions near the bottom of the photo resist pattern. This advantage produced better uniformity of land (and groove) dimensions. Figure 3 shows it clearly that the boundary wall between the land and groove has a very smooth surface and a good straightness in tangential direction. Such the superior flatness and the good uniformity of land and groove dimensions including groove walls totally induced a lower track noise than that of the fabricated disk by a photo resist master. The lower track noise led the good BER of MO signal, and brought wide system margins.

The RIE glass master has the other advantage for the mass production of substrate. One RIE glass master can produce multiple stampers. In general, the stamper for the injection molding is fabricated by electroforming a photo resist master. In this case, the photo resist pattern on a glass substrate is damaged when the stamper is peeled off the photo resist master

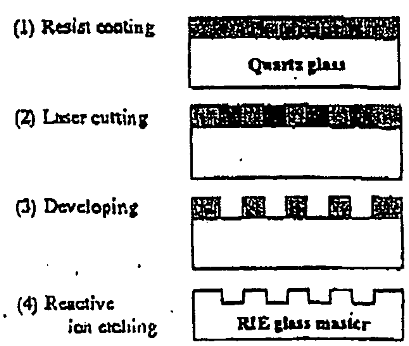


Figure 2: Disk fabrication processes.

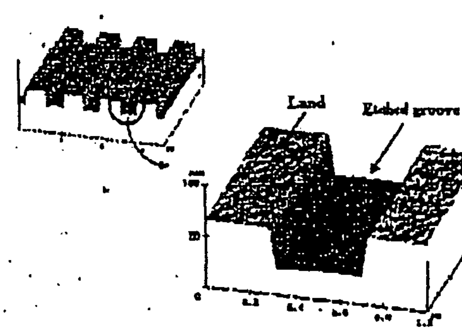


Figure 3: Atomic microscope image of reactive ion etched glass master.

after the electroforming process. Therefore, only one stamper can be obtained from one photo resist master. On the other hand the etched pattern sustains no damages. So multiple stampers can be obtained from one RIE glass master with good reproducibility. It is useful to product a large quantity of substrates with the same quality.

### 3.2 Injection molding

Desirable key functions for substrates in the MO field are: small birefringence, small tilt, and good duplicate ability. To meet these demands, an amorphous polyolefin polymer was employed as the substrate material in this study. It had better optical characteristics than a conventional polycarbonate polymer and had no difficulty in controlling the disk tilt and the duplicate properties of grooves in our injection molding process.

Figure 4 shows the birefringence of injection molded substrates of the amorphous polyolefin and the polycarbonate. The vertical axis indicates the retardation value for a single pass of a 633 nm wavelength light irradiated in normal direction to the substrate surface. A retardation value less than ±20 nm is preferable in practical use. The amorphous polyolefin met the demand in all radial positions. The polycarbonate showed large retardations at the inner radius area in our study.

Figure 5 reveals a typical data of axial deflection on the injection molding substrate. The maximum axial deflection was below 14 µm per revolution, and the radial and tangential tilts were +1.2 mrad. and +0.6 mrad., respectively. Those tilts are small enough for practical use. Additionally, the deviations of tilts between several hundred substrates were within 0.2 mrad. in both directions. A good reproducibility of tilts in the injection molding process was confirmed.

By the way, we should make a completed disk tilt be in a desirable value. The completed disk contains a CAD-MSR medium and a UV resin protective film formed on the substrate in this order. The radial tilt moves generally by forming a recording medium and a UV resin protective film, due to the unbalance of internal stresses. In our study, the movement was approximately −2 mrad. and the radial tilt of completed disk in this case was about −1 mrad. The tangential tilt was kept almost the same value of the substrate. Both radial and tangential tilts on the completed disk tilts are small enough for practical use. Our internal targets for the completed disk tilts were ±3.5 mrad. in radial, and ±2.5 mrad. in tangential direction. The fabricated disk in this study met the internal specifications with sufficiently wide production margins.

Figure 6 shows an AFM image of the injection molding substrate. The image indicates the good straightness of boundaries between lands and grooves, as well as the RIE glass master shown in Fig. 4. And also the centerline average roughness was less than 0.2 nm on both land and groove surfaces. The roughness was almost the same as those on the RIE glass master and the stamper. Thus we confirmed that the amorphous polyolefin revealed a good duplicate ability and generated a smooth surface in the injection molding process.

### 3.3 New UV resin material to reduce transient disk tilts

It is one of the most significant matters to keep a completed disk tilts constant whenever the surrounding environmental conditions change. We developed a new UV resin film and confirmed its ability for reducing the transient tilts[9].

In general, when the surrounding temperature or the humidity changes, a disk tilt changes by the difference of thermal or humidity expansion or contraction volumes between the substrate, the recording film, and the UV resin film. Conversely, it is possible to reduce the tilt movement by adjusting expansion (or contraction) volumes between them. In the case of the temperature expansion, the coefficient of thermal expansion of the CAD-MSR film is approximately one order less than

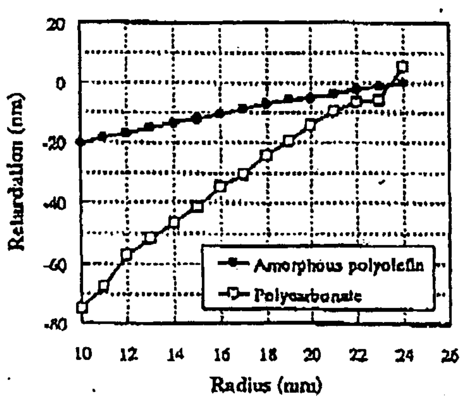

Figure 4: Birefringence of injection molding substrates.

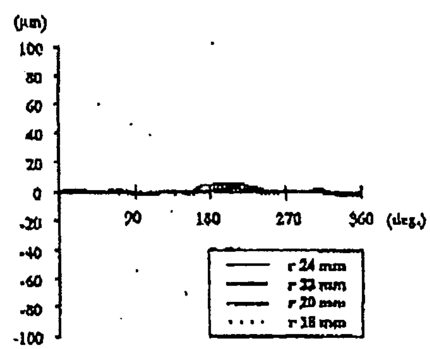

Figure 5: Axial deflection of injection molding substrate with 0.5 m m thickness.

hose of the substrate and the UV resin materials. Moreover, the humidity expansion of the CAD-MSR is supposed to be almost zero and can be negligible compared with other elements. So we modified the UV resin material to be balanced the thermal and humidity expansion volumes between the substrate and the UV resin film. In concrete, the UV resin material was modified to have a larger thermal expansion coefficient and a smaller humidity expansion coefficient than those of commercially used UV resin materials. Off course, the modified UV resin maintained other important roles: protection of recording layers and high lubrication ability for the magnetic head.

Figure 7 shows an experimental result for an environment test to confirm the new UV resin performance. The experimental disk consisted of: an amorphous polyolefin substrate with a 0.5 mm thickness, a CAD-MSR medium with about 200 nm total thickness, and a newly developed UV resin protective film with a 15 μm thickness. The horizontal axis indicates the exposure time and the sample disk had been placed in the environmental testing chamber. A laser displacement meter for measuring the sample disk tilt was also constructed in the testing chamber and the disk tilt was measured in real time. The vertical axis shows the radial tilt value. The minus tilt on the vertical axis indicates that the disk gets close to an optical head. The tilt change in tangential direction was very small within 0.3 mrad. in this test. So the tangential data were omitted graphing.

In this test, the sample disk had been placed in the testing chamber over 24 hours under a condition of 25°C-50%R.H. (relative humidity) to let the disk tilt reach to an equilibrium state. The 25°C-50%R.H. condition is very close to the room condition, so we defined the tilt value of the above equilibrium state as the completed disk tilt. The completed disk tilt in this test was +1 mrad. as shown in the figure. After confirming the completed disk tilt, the environmental condition was changed to 70°C-5%R.H. The 5%R.H. at 70°C had an important meaning that the absolute humidity, not relative humidity, was almost the same as the 50%R.H. at 25°C. So we could know the tilt change only by the temperature transition. It was only +0.7 mrad. Then the environmental condition was returned to 25°C-50%R.H., and we confirmed the disk tilt also turned back to the initial value. Then only the humidity was changed from 50 to 90%R.H. at 25°C. The tilt change only by the humidity transition was -1.6 mrad. The latter humidity change looked like large, but the absolute tilt value was in the range between +2.1 and -0.2 mrad. It was quite small value for reading/writing operations. And we should point out that; in the case of utilizing a commercially used UV resin material, the radial tilt exceeded 10 mrad. in our study.

Figure 8 shows the other result for a more severe testing condition. The test condition was compliant with internally defined operating conditions. The temperature range was -5 to 65°C and the humidity one was nearly 0 to 90%. In this test, the largest tilt change was about -2 mrad. at the condition change from 25°C-50%R.H. to 38°C-90%R.H. It was slight larger than the previous data shown in Fig. 7. It is caused that not only humidity change but also temperature change was added in this test. The humidity absorption became larger due to the higher temperature, we suppose. Nevertheless, the absolute radial tilt was sufficiently small and within 1.2 mrad.

In this test, we tried testing under the lower temperature condition than -5°C. However a condensation occurred and it prevented measuring the disk tilt. With making an estimate from the tilt shift result between 25 and -5°C, the predicted tilt at -25°C becomes -1.17 mrad. If the -25°C condition was adopted, the disk tilt would be kept in practicable range. In addition, the sample disk showed a good reversibility of tilt in other climatic environment tests: 80°C-90%R.H. for 240 hours and -25°C for 240 hours. It proofs that both materials of the UV resin and the substrate maintained their original characteristics even after such tight conditions.

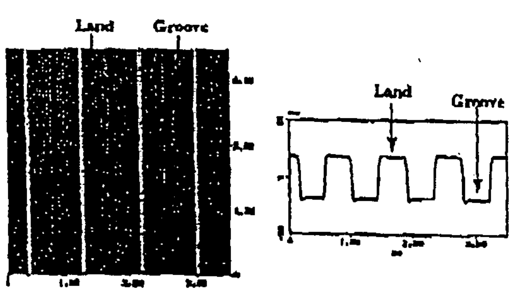


Figure 6: Atomic microscope image of injection molding substrate.

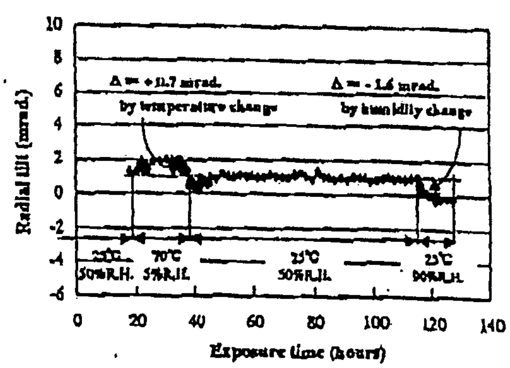


Figure 7: Disk tilt change in fundamental environment test.

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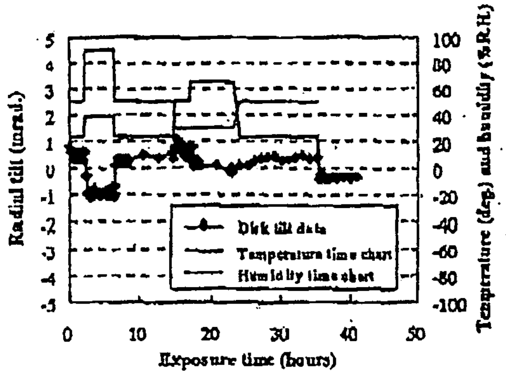


Figure 8: Disk tilt change in internally defined environment test.

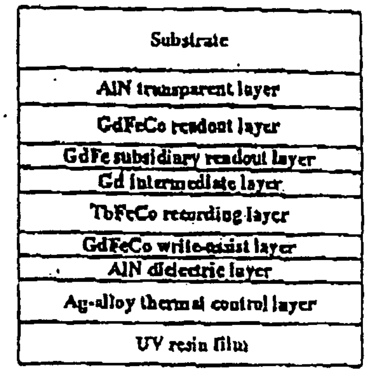


Figure 9: CAD-MSR medium structure in this study.

## 4. READOUT AND RECORDING PROPERTIES

Figure 9 shows the CAD-MSR medium structure in this study[7]. The major improvement points compared with that in the previous report[5,6] were as follows: A Gd intermediate layer was employed instead of a conventional non-magnetic layer made of Ag-alloy, and the tri-layer structured recording layers was changed to a single recording layer and added a write-assist layer. The former made the readout power margin wider and the latter made the recording power and magnetic field sensitivity higher.

Table 1 presents measurement conditions. The effective track pitch was 0.4 μm and land and recording was performed in this study. The recorded bit length for various system margin estimations was set to 0.146 μm. The areal bit density was 11 Gbits/in$^2$. The laser pulsed magnetic field modulation method was employed to realize higher track density recording and the recording pulse duty was set to 33%. The linear velocity was 3.2 m/s, and the recording magnetic field was 250 Oe. The data channel clock was 33 MHz and the (1,7) RLL (run-length-limited) coding was utilized. The partial response (PR) of (1,2,1) detection and the Viterbi detection methods were combined to evaluate the BER.

Figure 10 shows the BER dependence on the linear bit length. The recording channel clock was kept constant and the linear velocity was changed for each bit density in this measurement. The BER values on both land and groove were in constant over the bit length of 0.16 μm, and those values were near 1E-6. The BER value near 1E-6 indicates that the number of defects on the substrate is quite small, and the readout resolution of medium is sufficiently high. Our target bit density in this study was 0.146 μm length. A slight less of BER was observed but it was a relatively good BER value. Several system margins were investigated in the bit density.

Figure 11 shows the BER dependence on the recording laser power. We defined a recording power margin from this result. The readout power was 1.82 mW for land and 1.68 mW for groove. Both of those powers were the center readout power

Table 1 Measurement conditions.

| | |
|---|---|
| Wavelength | 406 nm |
| NA | 0.60 |
| Substrate thickness | 0.5 mm |
| Effective track pitch | 0.40 μm (L/G recording) |
| Recording bit length | 0.146 μm |
| Recording method | Laser pulsed MFM |
| Recording pulse duty | 33% |
| Linear velocity | 3.2 m/s |
| Recording magnetic field | 250 Oe |
| Channel clock | 33 MHz |
| Modulation code | (1,7) RLL |
| Data detection | PR(1,2,1) + Viterbi |

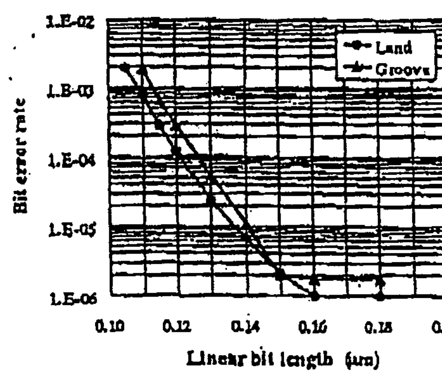


Figure 10: Bit error rate dependence on linear bit length.

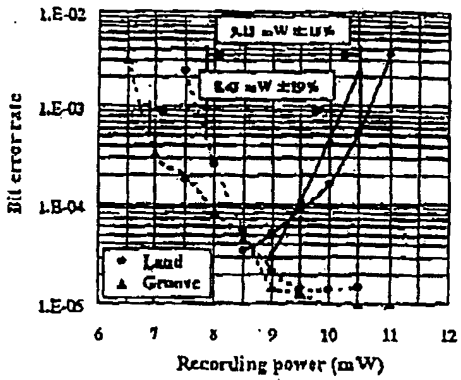

Figure 11: Bit error rate dependence on recording laser power.

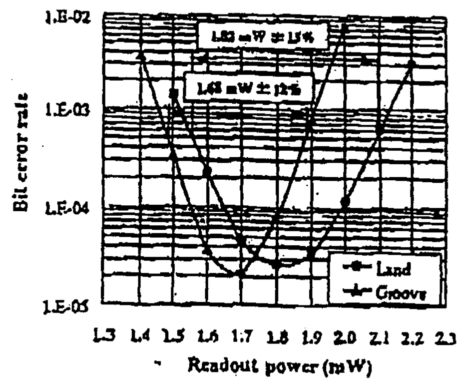

Figure 12: Bit error rate dependence on readout laser power.

obtained in a readout power margin measurement. The dotted lines show the BER for a 1-track recording state. The measured track had been pre-recorded with a large recording power above 10 mW, and after that the track was over-written with a small power. So residual domains exists if the overwrite power is too small. It was a severe condition to know the overwrite-ability. The adjacent tracks were in an as-deposition state, where no data was recorded. The solid lines show the BER for a 3-track recording state. The adjacent tracks were also recorded with the same recording power. The inserted numbers in the figure indicate recording power margins for land and groove. The BER criterion for determining the margin was 5E-4. It was equivalent to the limit of error correction ability in this study. The under limit of recording power was 7-8 mW. It was nearly equal as that in red laser systems we had been studied. It is acceptable recording power sensitivity for realizing a mobile disk drive system. The upper recording power was limited by the cross-write phenomenon dominantly, not by the cross-talk one. In blue laser recording, the peak temperature of the recording medium reaches higher than that of the red laser recording due to the higher energy density in the beam spot. Therefore, to let the heat out from the recording layer became more important and the CAD-MSR medium in this study had the countermeasure by increasing the thickness of thermal control layer. The thickness was changed from 40 to 70 nm in this study. It functioned effectively to reduce cross-write and a relatively large margin value was obtained as shown in Fig. 11. The internal specification for the recording power margin was ±15%. The experimental results were beyond it both land and groove. In the case of the 40 nm thickness, the margins were less than ±10%.

Figure 12 shows the BER dependence on the readout laser power. The measured track was the 3-track state recorded with the center recording power. The obtained margins were clear our internal spec ification of ±12% on both land and groove. Figure 13 shows disk tilt margins in: (a) radial, and (b) tangential directions, respectively. The measured track was the same 3-track state for estimating the readout power margin. In this measurement, the readout power was adjusted for each

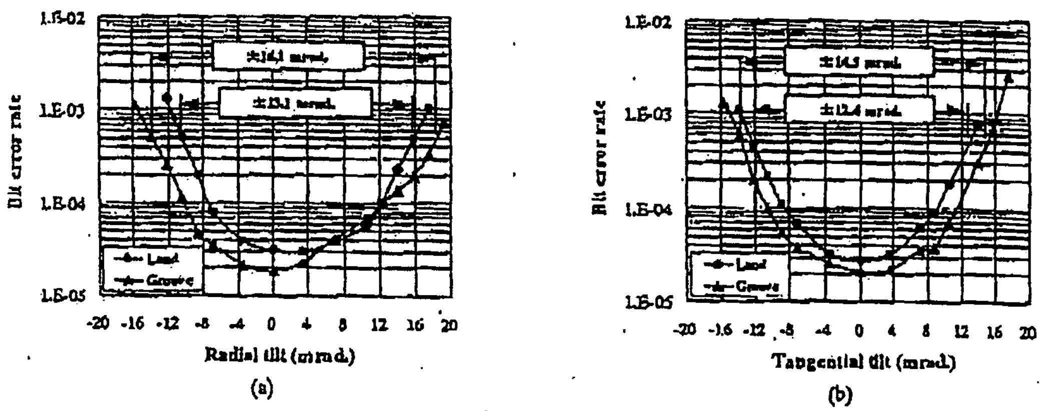

Figure 13: Bit error rate dependence on: (a) radial, and (b) tangential tilt.

tilt state. In the CAD-MSR system, controlling the aperture size is important to get wider tolerances for readout. When the disk tilts, the peak intensity of the focused readout beam decreases by coma aberration in comparison with that in the no-tilt state. In order to compensate the intensity loss and to get the same aperture size, a higher readout laser power is needed. Consequently, the larger the tilt, the larger the readout power becomes. The internal specifications were ±10 mrad. for radial and ±6 mrad. for tangential directions. The obtained margins were large enough compared with the specifications. It is noted that such wide enough margins were generated by combining of the moderate 0.6 NA lens, the thin 0.5 mm substrate, and the CAD-MSR medium.

Table 2 lists experimental results and internal specifications for each item. The readout power margin for the groove and the recording power margin for the land were very close to the internal specifications but all of experimental results satisfied the specifications. Additionally, the radial and tangential tilt margins were sufficiently wider than the specifications. It suggests that the 0.5 mm thickness disk can be applied to higher numerical aperture systems as like 0.65 or 0.7. Realizing larger capacity disk system is to be expected.

Table 2 Margin list of experimental results and internal specifications.

| | Experimental results | Int. spec. |
|---|---|---|
| Readout power | Land 1.82 mW ±15%<br>Groove 1.68 mW ±12% | > ±12% |
| Recording power | Land 8.15 mW ±15%<br>Groove 8.43 mW ±18% | > ±15% |
| Radial tilt | Land ±13.1 mrad.<br>Groove ±18.1 mrad. | > ±10 mrad. |
| Tangential tilt | Land ±12.4 mrad.<br>Groove ±14.5 mrad. | > ±6 mrad. |
| Total disk tilt (A+B) (radial direction) | < ±3.22 mrad. | < ±5.25 mrad. |
| A: Fabricated disk tilt | < ±2.00 mrad. | < ±3.50 mrad. |
| B: Change in environment tests | < ±1.22 mrad. | < ±1.75 mrad. |

## 5. CONCLUSIONS.

We confirmed that a 2 GB user-capacity CAD-MSR disk with a 50 mm diameter was accomplished with practicably available margins. The experimental optical head consisted of a blue laser diode and an objective lens of 0.6 NA. The areal recording density reached to 11 Gbits/in$^2$ with land and groove recording of 0.4 μm wide tracks. The disk substrate thickness was 0.5 mm. We confirmed the injection molding of the 0.5 mm substrate was possible with small tilt, good duplicative ability, and good optical properties. We also developed a novel UV resin material to keep the completed disk tilt small even if the surrounding climatic condition changed. The CAD-MSR medium was improved to match blue recording and it generated superior readout resolution and good sensitivities for the recording laser power and the recording magnetic field. The accomplished CAD-MSR disk produced available system margins for practical use.

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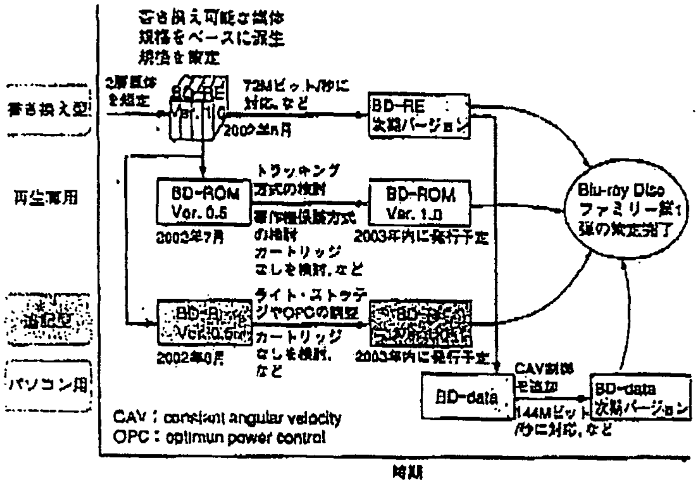


図4 2003年内を目標に再生専用と追記型の媒体規格を策定
Blu-ray Disc規格のうち，策定を終えたのは書き換え可能な媒体の規格である。現在，再生専用媒体や追記型媒体などの規格を策定中で，2003年内にも規格書を発行する予定だ。このほか，パソコン用途も検討中だ。

いうことだけではなく，ユーザーの心をグッと引き付けるような新機能の導入が不可欠だと考えたからである。VHS方式の磁気テープからDVD-Videoディスクに移行する際にもDVDメニューに代表される対話型の操作など，新機能の導入がひと役買っている。

BD-ROMは現在，米国映画業界などからの要望を反映する形で規格策定作業を進めている。規格は完全には固まっていないが，DVDを超える対話型操作や，ブロードバンド回線を利用したインターネット・サービスとの連動機能などを盛り込む予定である。

## 再生専用/追記型規格は2003年内に

Blu-ray Discの規格を拡張していくに当たり我々は，書き換え可能な媒体規格「BD-RE Ver. 1.0」をベースに後続規格を派生させる「Transfer all features」の思想を貫く(注3)。例えばディスク片面単層の記録容量は，BD-RE Ver. 1.0で固めた23.3Gバイト，25Gバイト，27Gバイトを堅持する。データ転送速度も36Mビット/秒を標準値とし，今後のすべての規格を定めていく計画である（図4）。

BD-ROMとBD-Rについては，2003年内に「BD-ROM Ver. 1.0」「BD-R Ver. 1.0」として規格化する予定である(注4)。この際に物理層も拡張する。例えばBD-ROMではトラッキング方式を追加する。BD-REで採ったPP(push-pull）方式†に加えて，再生専用ディスクのピット列を追跡するのに優れたDPD (differential phase detection）方式†を加える方向だ。BD-REで採用したカートリッジも不要とする予定である。

BD-Rでは，ライト・ストラテジ†やOPC (optimum power control）†のパラメータなどを同媒体の記録膜に向けて修正する。カートリッジも不要とし，当初から2倍速（72Mビット/秒）記録を盛り込む予定だ。片面2層ディスクの規格化も検討している。

BD-RE規格もVer. 1.0からの拡張を進める。次期バージョンではまず，BD-Rと同じく2倍速記録の導入を計画している。

BD-RE規格は光ディスク録画機などのAV機器を主なターゲットにしているが，実はパソコン用の記録媒体として使える仕組みも既に盛り込んである。現在のところ，新たにパソコン用規格「BD-data」を策定するかは未定だが，拡張は容易だ。高速記録が重視されるパソコン用途では，早期に4倍速(144Mビット/秒)への対応が進むことになるだろう(注4)。このときにはディスクの回転制御方式を現行のBD-RE規格のCLV (constant linear velocity)からCAV (constant angular velocity)に変更する必要があると考えている。

BD-RE，BD-ROM，BD-R，BD-dataなどの拡張によって，第1世代のBlu-ray Discファミリー規格が完成することになる(注4)。このほかに小径媒体などの実用化も視野に入れている。例えば，CDやDVDのような直径8cmの媒体に格納できる容量を計算すると，ディスク片面単層で約7.5Gバイト。直径12cmの片面単層DVDディスクの1.5倍に当たるデータを格納できる。

注3）Blu-ray Disc規格を策定するに当たっては，同規格のベースとなっているBD-RE規格を策定した中核技術者が，必ずBD-ROM規格やBD-R規格を検討する会議にも出ることにしている。こうすることで常にBD-RE規格を受け継いだ一貫性のある派生規格にしていくことを狙っている。

注4）物理層だけではなく，ファイル・システム層やアプリケーション層までを規定した完全版を発行する。

†PP (push-pull）方式＝トラッキング・エラー信号を得る手法の1つ。ディスクの記録面で反射・回折した光を，トラックを中心線として対称に配置した2つの光検出器でとらえる。そして2つの検出器で受けた光量の差を検出し，左右へのズレ量を得る。1本のレーザ・ビームで同信号を検出できることが特徴。ビームを3分割してトラッキング・エラー信号を検出する3ビーム法に比べて光の利用効率が高い。このため，できるだけ多くの光出力を確保することが必要な記録型の光ディスク装置などに向く。

†DPD (differential phase detection）方式＝DVD-ROMのような再生専用ディスクに対してよく使われるトラッキング・エラーの検出方式。レーザ・ビームがピット列の左側にズレているか，右側にズレているかで回折パターンが変わることを利用し，ズレ量を求める。ただ，ピットの深さがλ/4（λ：波長）の場合にトラッキング・エラー信号が最大になる。PP方式などに比べてピットの深さのバラつきによる影響を受けにくいなどの特徴がある。

## 大容量化のカギを握る 0.1mmカバー層方式

策定を終えたBD-RE規格は，全体を3つの技術に分けると理解しやすい。①ディスク構造や光学系の構成，信号処理技術などを規定する物理層の技術，②ディスクに対するアクセス方法などを規定するファイル・システム層と，ユーザーに提供する機能などを規定するアプリケーション層の技術，③コンテンツを守る著作権保護技術，である。ここからは，それぞれの技術について順に解説し，BD-RE規格の実体を明らかにしたい（表1）。

### チルト・マージンをDVDと同等に

BD-REでは，DVDの5倍という面記録密度を実現するために，光ディスクの基本的なパラメータを一から見直した。すなわちレーザ光のビーム・スポット径を絞るために，光源波長λを短くし，対物レンズの開口数NA（numerical aperture）を高めた。一般にビーム・スポット径はλに比例しNAに反比例する。今回は両方を変えることで，一気にビーム・スポット径を縮小した。

具体的には，光源に波長405nmの青紫色レーザを採用した[注3]。現行DVDの650nmに対して約4割減である。一方，対物レンズのNAはDVDの0.6から0.85に増やした[注4〜5]。これらの変更により，ビーム・スポットの面積をDVDのものに比べて約1/5に縮めた。つまり，DVDに比べて5倍の面記録密度で記録マークを読み書きできる。

ただし，この方法を採ると新たな課題が浮上する。NAを高めるにつれて，その3乗に反比例してディスクとレーザ光の光軸の傾きに許される角度誤差（チルト・マージン）が狭くなってしまうのだ。これは，ディスク製造や装置の組み立てに許される機械的な誤差が極端に小さくなることを意味する。そこで今回はチルト・マージンを広げるために，記録膜面を覆うカバー層を0.1mmまで薄くした（pp.36-37の「光透過層は薄くても問題ない，デフォーカスと誤り訂正は補完関係に」参照）。こうすることで，チルト・マージンは現行DVD並みの±0.75度を確保した。

### 現行DVDのディスク構造を断念

この結果，今回のディスク構造は現行DVDに比べて大きく異なることとなった（図5）。DVDでは厚さが0.6mmのディスク基板2枚を張り合わせている（以下，0.6mm基板張り合わせ方式）。これに対してBlu-ray Discは，厚さが1.1mmのディスク基板上に記録層を設け，0.1mmの透明なカバー層で覆う構造である（以下，0.1mmカバー層方式）。

もちろん当初は，現行DVDと同じ0.6mm基板張り合わせ方式も検討した。その方が，現行DVDとの互換性を確保しやすいからだ。しかし，最終的に同構造を採ることは難しい

*ライト・ストラテジ＝1つの記録マークを書き込むとき，その形状が歪まないように，半導体レーザを駆動する電流波形をパルス状に変化させる。この波形パターンをライト・ストラテジと呼ぶ。パルスの振幅や周期を変えることで記録マークを所望の長さにしたり，後半部がトラックの幅方向に広がってしまうのを防ぐ。ライト・ストラテジは一般に，媒体の記録膜や記録速度により異なる。

†OPC（optimum power control）＝記録膜の感度や半導体レーザごとの波長バラつきによる記録状態の違いを補正するためにレーザの光出力を調整すること。媒体の試し書き領域を使って適切な値を自動判断する。

注5）光ディスクの回転速度の限界を仮に1万rpmほどとすると，ディスク最外周における線速度は12倍速付近に達する。このときのデータ転送速度は，Blu-ray Discの面記録密度だと約400Mビット/秒になり，ハード・ディスク装置に匹敵する水準になる。

注6）Blu-ray Discのさらに次世代を担う光ディスク規格では，数百Gバイトの容量が期待されるだろう。その際はBlu-ray Discの技術をベースとして，多値記録や多層記録，新しい信号処理といったハードウエアによる大容量化と，符号化技術などソフトウエアによる大容量化の両面で容量拡大を模索していく必要がある。

表1 「BD-RE Ver.1.0」の主な仕様

| | | | |
|---|---|---|---|
| 片面単層の記録容量（片面2層媒体の場合） | 23.3Gバイト（46.6Gバイト） | 25Gバイト（50Gバイト） | 27Gバイト（54Gバイト） |
| 光源の標準発振波長 | 405nm | | |
| ディスク直径 | 12cm（内径15mm） | | |
| ディスクの厚さ | 1.2mm | | |
| 記録膜を覆うカバー層の厚さ | 0.1mm | | |
| 対物レンズの開口数 | 0.85 | | |
| トラック・ピッチ | 0.32μm | | |
| 記録膜 | Ge-Sb-Te系や共晶系などの相変化記録膜 | | |
| 最短記録マーク長 | 0.16μm | 0.149μm | 0.138μm |
| 面記録密度 | 16.8Gビット/(インチ)² | 18Gビット/(インチ)² | 19.5Gビット/(インチ)² |
| 回転制御方式 | CLV | | |
| 標準のデータ転送速度 | 36Mビット/秒 | | |
| 記録トラック方式 | グルーブ記録 | | |
| アドレス方式 | ウォブル方式*1 | | |
| 記録符号化方式 | 1-7PP*2 | | |
| 誤り訂正方式 | LDCとBISを組み合わせる方式 | | |
| 映像記録方式 | MPEG-2トランスポート・ストリーム | | |
| 音声符号化方式 | DolbyDigital，MPEG-1 LayerⅡなど | | |

*1 松下電器産業が提案した「STW」方式と，ソニーが提案した「MSK」方式を組み合わせた方式。
*2 (1, 7) RLL符号を改良したParity Preserve/Prohibit RMTR（repeated minimum transition runlength）の略。ソニーが提案した。
BIS：burst indicating subcode　CLV：constant linear velocity
LDC：long distance code　MSK：minimum shift keying　STW：saw tooth wobble

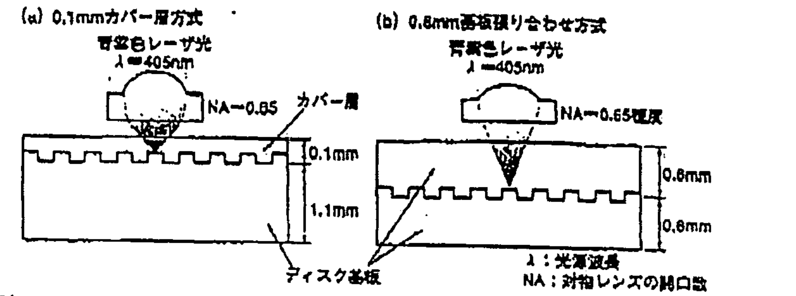


図5 厚さ0.1mmのカバー層を採用
DVDの次世代光ディスクを開発するに当たって，主に2種類の光学系を検討した。1つは，厚さ1.1mmのディスク基板上に記録層を設け，厚さ0.1mmのカバー層で覆う方式（a）。開口数（NA）が0.85と高い対物レンズでデータを読み出す。もう1つはDVDと同じく，厚さ0.6mmのディスク基板を張り合わせる方式である（b）。対物レンズのNAは0.65程度になる。Blu-ray Discでは0.1mmカバー層方式を採用した。

と判断した。理由は次の通りだ。

まず第1に，記録容量を20Gバイト以上に高めるのが難しい。現行DVDと同じ構造で単に光源波長を短波長化しただけでは，記録容量を12Gバイト程度までしか高められない[注10]。記録マークの間隔を詰める一方でデータを的確に読み取るためにPRML（partial response maximum likelihood）技術を導入する手法も試みたが，所望の記録容量には到達できなかった。

面記録密度を高める方法には，ディスクに形成したトラックの凸部と凹部の両方に記録する，いわゆる「ランド・グルーブ記録」を使う方法もある。この方法で隣り合うトラック間のクロストークを抑えながら，トラック・ピッチを詰める手法も検討した。しかし，レーザ光のビーム・スポット径が小さくなっても熱が伝播する範囲はそれほど狭まらない。従ってトラック・ピッチを縮めた分，隣接トラックへの熱伝搬の影響は大きくなる。この結果，記録時に隣接トラックのデータを消してしまうという問題（クロスイレーズ）が起こり，これを克服できなかった。

片面2層ディスクを使ってこの壁を乗り越えようと考えたが，0.6mm張り合わせ方式だと，この手法を採用することも難しいと判断した。現行DVDとほぼ同じNAが0.6程度の対物レンズで絞ったビーム・スポットのパワー密度は，NA0.85の場合の半分近くまで低下してしまう。ビーム・スポットの面積が約2倍に広がるためだ。現在，BD-REで片面2層ディスクに記録するためにパルス発振で約50mWの光出力が必要になることを考えれば，0.6mm基板張り合わせ方式では100mWを超える青紫色半導体レーザが必要になる。これは現時点では手に入らない。

確かに光ディスク関連の学会では，0.6mm基板張り合わせ方式とNAが0.65の対物レンズ，PRML処理などを組み合わせて記録容量を20Gバイトまで高めた成果も報告されている[1]。しかしこの場合，前述のチルト・マージンが±0.3度程度と現行DVDの半分近くまで狭くなってしまう。ここまで狭いと，このディスクと光軸の傾きを補正する機構（チルト・サーボ）を光ピックアップに追加する必要がある。ただし，ディスクが変形している場合は，回転に同期してこの傾き量も変動する。これに高速に追従できる機構を光ピックアップに実装するのは難しい。動的に正確なチルト角を検出するのにも限界がある。このため，0.6mm基板張り合わせ方式の採用は事実上，困難だと考えた。残る選択肢の中で最も有望なのが0.1mmカバー層方式だった。

## 1レンズで互換性確保が可能に

BD-RE規格の録画機を製品化する場合，

注7）青紫色レーザの光源波長である405nmより短波長の光源（紫外線レーザ）も検討したことがある。しかし，400nmより短い波長ではポリカーボネートなどの基板材料の吸収率が急増し，レーザ光が透過しにくくなる。さらに，紫外線の照射により基板材料が劣化する問題もある。

注8）対物レンズの標準的な開口数（NA）は，CDの場合に0.45，DVDでは0.6だった。一般にNAが高いほどレンズの面精度などに対する要求は厳しくなる。0.45と0.6は，その当時に量産が見えているレンズの中で最も高いNAの値だった。Blu-ray Discでは，レンズを2枚重ねてNAを0.85に高める方法を提案した。2枚のレンズはそれぞれDVDのレンズの製造技術があれば作ることができる。この2枚組レンズは，光学設計にもよるが，ディスクとレンズの間隔（WD：working distance）を0.14mm程度まで近づける必要がある。このためレンズとディスクの衝突を懸念する声が多い。WDが小さいと衝突の確率が高まることは否めないが，振動を検出して保護する回路を取り付けるなど万一に備えることは可能である。さらに最近では1枚のレンズでNAを0.85まで高めたレンズが開発されている。同レンズはWDが0.5mm程度と広いため，実用上問題にならないだろう。

注9）光源波長が短く，NAが大きい光学系を使うと，記録時はレーザの光出力を抑えられるという利点がある。ビーム・スポット径を絞り込む分，レーザ光のエネルギーが集中するためだ。現行DVDの光学系である波長650nmの赤色レーザ光とNAが0.6の対物レンズの組み合わせと比べて，Blu-ray Discの波長405nmの青紫色レーザ光とNAが0.85の対物レンズの組み合わせでは，記録に必要な半導体レーザの光出力がおよそ1/4で済む。例えば，片面単層のBD-RE媒体に36Mビット/秒の速度で記録する場合，記録面上の最大光出力は5.2mW，片面2層媒体では10.4mWでよい。なお，図6の下部にCD，DVD，Blu-ray Discそれぞれのビーム・スポット径と強度分布を示した。

注10）0.6mm基板張り合わせ方式を採用している現行の記録型DVDでは，チルト・サーボを用いてNAを0.65程度に高めている例がある。しかし，それ以上にNAを上げるのはチルト・サーボの性能上，難しい。一方，光源波長を短くしてもチルト・マージンは狭くなる。例えば光源波長を405nmに短波長化しながらチルト・マージンを維持しようとすると，短波長化による収差量の増分を打ち消すためにNAを0.65から0.55程度まで下げなければならない。NAが0.55まで下がると，結果的に実現できる記録容量は10Gバイト程度まで減少してしまう。

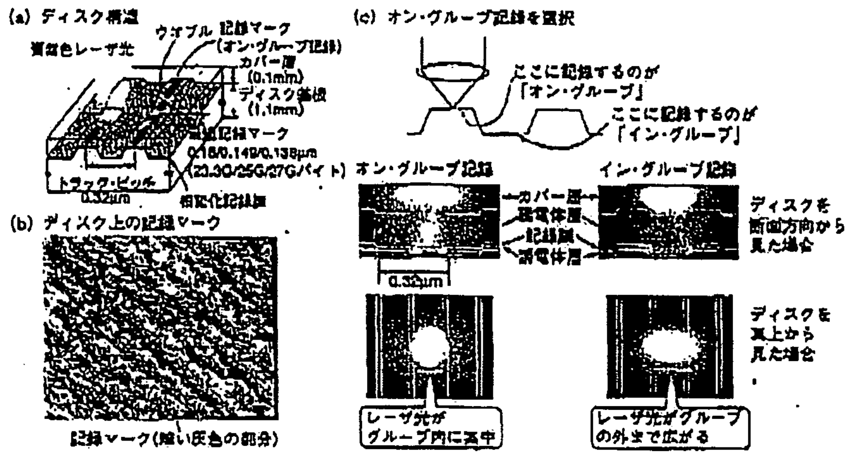


図8 「オン・グループ」にマークを記録
(a) にBlu-ray Discの書き換え可能な媒体のディスク構造を示した。ディスク上に刻んだ凹凸の一方のみにデータを記録する、いわゆるグループ記録を採用している。(b) は実際にマークを記録したディスクを真上から見た電子顕微鏡写真である。データは、青紫色レーザ光源の入射方向から見た場合の凸部(オン・グループ)に記録する (c)。電磁計算によるシミュレーションの結果、オン・グループ記録ではレーザ・ビームがグループ内に集中するのに対し、凹部(イン・グループ)の場合はグループの外側まで広がることが分かった。

少なくとも現行DVD媒体との再生互換性を確保することが必要になるだろう。このとき0.1mmカバー層方式ではディスク構造や対物レンズなどの光学系が大きく変わるため，互換性の確保が難しいと指摘する声がある。しかし，この課題解決にはメドが付いている。

最も確実な方法は，それぞれの対物レンズを別に用意して切り替える方法である。しかし，こうすると光学部品の数は多くなってしまう。このため，DVDとBD-RE媒体で1つのレンズを共有する技術開発も進んでいる。これは，DVDの赤色半導体レーザ光とBD-REで使う青紫色半導体レーザの波長の違いを利用してNAやカバー層の厚さの違いを吸収しようというものだ[注11]。既に複数メーカーがこうした技術の開発を発表しており，展示会などでデモンストレーションを行った例も出てきている。

実は，DVDが登場したときも同じ課題を抱えていた。CDに対して光源波長を短くし，対物レンズのNAを増やし，ディスク基板の厚さを1.1mmから0.6mmに減らしたからだ。このときも当初は，対物レンズを切り替えていた。しかし今では1レンズで共有する方式が当たり前である。現在のDVD装置には，CD-Rの再生に向けた赤外半導体レーザとDVD再生用の赤色半導体レーザが搭載されており，光源波長の違いを利用してNAやディスク基板の厚さを切り替えている[注12]。技術のハードルの高さに違いはあるが，1レンズでBD-REとDVDに対応する録画機が登場するのも時間の問題だろう。

## トラック構造/信号処理技術の「いいとこ取り」を実現

BD-REのディスク構造の特徴は0.1mmカバー層方式だけではない。記録型DVDの技術開発で培った経験が散りばめられている。具体的には今回，DVD-RWやDVD-RAM，DVD+RWから優れた特徴を抽出してBD-RE規格向けに改良し，採用している[注13]。

まずDVD-RWからは，ディスクに刻み込まれたトラックの溝に記録する，いわゆる「グループ記録」を継承した (図8)[注14]。グループ記録を採用した理由は，現在策定中のBD-ROMやBD-Rとの再生互換性を確保するためだ。ランド・グループ記録を採用して

注11) Blu-ray Disc検討過程において，DVDとの再生互換性を確保するためには，赤色半導体レーザの搭載は必須となる。同レーザを搭載しないと，片面2層の再生専用DVDディスクが読めないからだ。片面2層ディスクは，レーザ光の入射方向から見て手前の記録層の反射膜としてAuやSiを使っている。これらは波長選択性が極めて強い。AuはI青紫色レーザ光を吸収するため，奥側の記録層が読めなくなる。Siは青紫色レーザ光をほとんど反射しないため，手前の記録層が読めなくなる。

注12) CDを再生する場合，赤外レーザ光は対物レンズの中央付近のNAが低い部分だけを選択的に通るようにする。さらに，波長依存性の強い光学素子を挿入してディスク基板の厚さの違いを吸収している。

注13) 一般に光ディスクの規格策定は再生専用ディスクから始まる。このため，その後から規格を策定することになる記録型媒体は，再生専用規格との互換性に気を配りながら規格を定めてきた。今回は書き換え可能な媒体規格から策定した結果，こうした制約に縛られずに済んだ。こうした状況が「いいとこ取り」の規格を生んだともいえる。

注14) 書き込み可能な光ディスクの記録トラック方式は主に2種類ある。ディスクに形成したトラックの凸部と凹部のいずれか一方だけに記録する「グループ」記録と，両方に記録する「ランド・グループ記録」である。現行の光ディスクではCD-R/RW，DVD-R/-RW，DVD+R/+RWなどがグループ記録を採用する。グループ記録は，さらに2つに分けられる。レーザ光の入射方向から見て凸側のトラックに書き込む「オン・グループ記録」と凹側に書き込む「イン・グループ記録」である。CDやDVD系の記録型光ディスクではずっとイン・グループ記録を採用してきたが，今回のBD-RE規格ではオン・グループ記録を採る。これはシミュレーション結果や実験結果から導き出した。例えば図8 (c) に示すシミュレーション結果では，オン・グループ記録の方が，レーザ・ビームがグループ内に集中していることが分かる。トラック・ピッチは0.32μm (溝幅0.16μm) とした。一方のランド・グループ記録はDVD-RAMなどが採用する。同じトラック・ピッチ (または面記録密度) の場合，トラックの幅をグループ記録の2倍近くに広げられるのが特徴だ。

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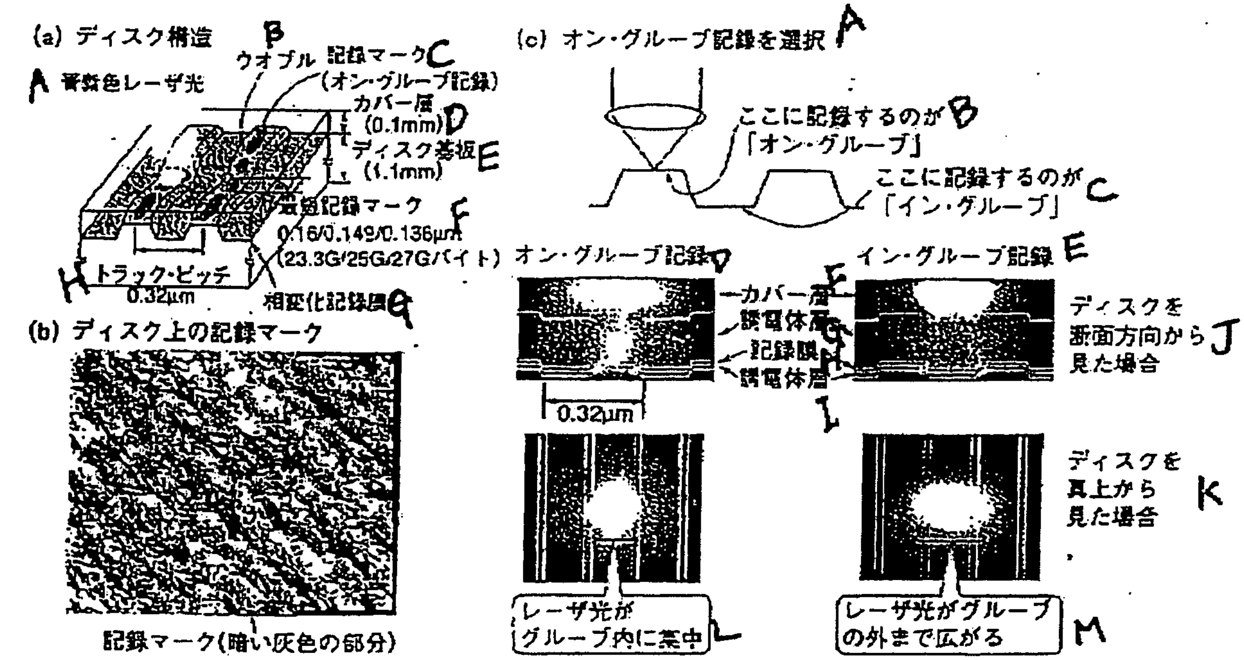


図6 「オン・グルーブ」にマークを記録
(a) にBlu-ray Discの書き換え可能な媒体のディスク構造を示した。ディスク上に刻んだ凹凸の一方のみにデータを記録する，いわゆるグルーブ記録を採用している。(b) は実際にマークを記録したディスクを真上から見た電子顕微鏡写真である。データは，青紫色レーザ光源の入射方向から見た場合の凸部（オン・グルーブ）に記録する (c)。数値計算によるシミュレーションの結果，オン・グルーブ記録ではレーザ・ビームがグルーブ内に集中するのに対し，凹部（イン・グルーブ）の場合はグルーブの外側まで広がることが分かった。

少なくとも現行DVD媒体との再生互換性を確保することが必要になるだろう。このときが当たり前である。現在のDVD装置には，CD-Rの再生に向けた赤外半導体レーザと

注(1) Blu-ray Disc録画機において，DVDとの再生互換性を確保するためには，赤色半導体レーザの搭載は必須となる。同レーザを搭載しないと，片面2層の再生専用DVDディスクが読めないからだ。片面2層ディスクは，レーザ光の入射方向から見て手前の記録層の反射膜としてAuやSiを使っている。これらは波長選択性が極めて強い。Auは青紫色レーザ光を吸収するため，奥側の記録層が読めなくなる。Siは青紫色レーザ光をほとんど反射しないため，手前の記録層が読めなくなる。

注(2) CDを再生する場合，赤外レーザ光は対物レンズの中央付近のNAが低い部分だけを選択的に通るようにする。さらに，波長依存性の強い光学素子を挿入してディスク基板の厚さの違いを吸収している。

Table 1 (Major specs for BD-RE Ver. 1.0)

| | | | |
|---|---|---|---|
| Storage Capacity for Single-sided, Single Layer (Two layers on each side) | 23.3 Gb (46.6 Gb) | 25 Gb (50 Gb) | 27 Gb (54 Gb) |
| Wavelength of Standard Oscillation of Light Source | 405 nm | | |
| Diameter of Disc | 12 cm (internal diameter 15 mm) | | |
| Thickness of Disc | 1.2 mm | | |
| Thickness of Cover Layer for Recording Layer | 0.1 mm | | |
| Aperture of Objective Lens | 0.85 | | |
| Track Pitch | 0.32 µm | | |
| Recording Film | Phase change recording film (ex. Ge-Sb-Te or eutectic) | | |
| Minimum Recording Mark Length | 0.16µm | 0.149µm | 0.138µm |
| Surface Recording Density ($Gb/inch^2$) | 16.8 | 18 | 19.5 |
| Rotation Control | CLV | | |
| Standard Data Transfer Rate | 36 Mb/second | | |
| Recording Track | Groove Recording | | |
| Address | Wobbling*1 | | |
| Encoding | 1-7PP*2 | | |
| Error Correction | Combination of LDC and BIS | | |
| Image Recording | MPEG-2 Transport Stream | | |
| Sound Encoding | DolbyDigital, MPEG-1 Layer II, etc. | | |

*1 Combination of "STW" proposed by Matsushita and "MSK" by Sony.

*2 Abbreviation for "Parity Preserve/Prohibit RMTR (repeated minimum transition runlength)," a modification to (1,7)RLL proposed by Sony.

BIS: burst indicating subcode

CLV: constant linear velocity

LDC: long distance code

MSK: minimum shift keying

STW: saw tooth whole

Fig. 6

(a) shows the structure of a rewriteable Blu-ray disc. The disc employs "groove recording" where data is recorded either on the land or the groove on the disc. (b) is an electron microscope image looking straight down on recorded marks. Data is recorded on the groove (on-groove) as seen from the direction of incident light from a blue-violet laser device (see (c)). A numerical simulation demonstrated that the laser beam concentrated in grooves in on-groove recording and expands beyond grooves in in-groove recording.

(a) Disc structure

A: Blue-violet laser beam

B: Wobble

C: Recording mark (on-groove recording)

D: Cover layer (0.1 mm)

E: Disc substrate (1.1 mm)

F: Minimum recording mark

0.16/0.149/0.138 µm for 23.3/25/27 Gb

G: Phase change recording film

H: Track pitch

(b) Recording marks (appearing dark gray) on disc

(c) A: On-groove recording selected

B: Data is recorded here in on-groove recording.

C: Data is recorded here in in-groove recording.

D: On-groove recording

E: In-groove recording

F: Cover layer

G: Dielectric layer

H: Recording layer

I: Dielectric layer

J: Disc as seen from cross-sectional direction

K: Disc as seen from above

L: Laser beam concentrates in grooves

M: Laser beam expands beyond grooves